

WATER REUSE TECHNOLOGY DEMONSTRATION PROJECT

Demonstration Facility Pilot Study Fuzzy Filter For Primary And Tertiary Treatment Final Report

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By

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BLACK & VEATCH



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Department of Natural Resources and Parks
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Technology Assessment Program

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Executive Summary

The Fuzzy Filter, manufactured by Schreiber, is one of eight unit processes that were tested during the King County Water Reuse Demonstration Project. The Fuzzy Filter is a relatively new filtration technology that has several unique properties. Its media is highly porous and compressible. The media properties can be changed, by varying media compression, to meet the filtration requirements of different influent characteristics. Therefore, the filtration rates are much higher than for conventional filters.

A four-square-foot pilot unit with a nominal media depth of 35 inches was supplied for the pilot test. The Fuzzy Filter was tested between October 15, 2001, and March 25, 2002 under varying operational conditions in three different treatment scenarios:

- **Primary Treatment** – Treatment of screened and de-gritted primary clarifier influent with no chemical addition
- **Tertiary Treatment with No Chemicals** – Treatment of secondary clarifier effluent with no chemical addition
- **Tertiary Treatment with Chemicals** – Treatment of secondary clarifier effluent with the addition of coagulants

Summary of Results

Primary Treatment

The Fuzzy Filter does not appear to be suitable for use in treatment of primary influent. Breakthrough of solids was observed after a short filter run time (i.e., less than one hour). This breakthrough was due to the high solids loading and the nature of the primary influent solids. As the filter was loaded, the larger primary solids rapidly accumulated at the very bottom of the filter bed. After this rapid accumulation, the pore space available to flow was clogged and flow began to bypass the filter bed, traveling along the sidewalls instead. This led to an increase in turbidity, and likely suspended solids, in the effluent. Since only a small amount of solids was being removed from the flow, only a small amount of solids was being stored within the media bed.

Because the solids storage capacity of the media bed was greatly reduced by the blinding effect, and the filter run times were extremely short, using the Fuzzy Filter for primary treatment would require an extremely large number of filters and would generate a high backwash volume. Therefore, the Fuzzy Filter is not recommended for treatment of primary influent.

Tertiary Treatment With No Chemical Addition

The Fuzzy Filter appears to be acceptable in the treatment of secondary effluent without the addition of chemicals under the conditions tested. Two different testing phases were carried out for treatment of secondary effluent with no chemical addition: operational condition testing

and extended testing. The Fuzzy Filter was tested at conditions ranging from 10 gpm/ft² to 40 gpm/ft² (40 gpm to 160 gpm loading rate) and 10 to 30% compression. Based on the results of the testing performed in this study, the following observations can be made:

- The effluent quality achieved by the Fuzzy Filter was dependent on the influent characteristics.
- Secondary effluent (Fuzzy Filter influent) characteristics were dependent on operating conditions at the West Point plant. During high flows, process instability, and bypass events, turbidity in the influent increased significantly.
- During operation of the Fuzzy Filter, when the automated wash cycle pressure set point was set at 1.75 psi above the clean bed filter influent pressure, average effluent turbidities of less than 2 NTU were observed when the average influent turbidity was below 3 NTU. Breakthrough of turbidity (i.e., values above 2 NTU) was observed toward the end of filter runs under these conditions.
- Observed filter run times varied depending on influent loading conditions and the operating conditions (i.e. bed compression, hydraulic loading rate, and wash cycle pressure set point) used with the filter.
- The reduction in wash cycle set point had a beneficial effect on the average effluent turbidity observed, but decreased the filter run times. In a full-scale facility, effluent turbidity monitoring should be used as an additional control parameter to initiate a wash cycle when a set point effluent turbidity is reached.
- Extended testing indicated that average effluent turbidities of 2 NTU were achieved at average influent turbidities of up to 5.3 NTU when the Fuzzy Filter was operated at 20% compression, 30 gpm/ft² loading rate, and a wash cycle pressure set point of 4 psi. An effluent turbidity of less than 2 NTU was achieved 90% of the time when the average influent turbidity was 4.4 NTU and the maximum turbidity was 10 NTU.
- Although the requirement to waste less than 8% water wasted was achieved under optimum conditions, the filter run times ranged from two to ten hours. At the shorter filter run times, full-scale feasibility is questionable, particularly under conditions of high loading. Depending on influent conditions, the filter run times can be increased by decreasing influent flow rate or increasing the wash cycle pressure set point.
- The hydraulic loading rates demonstrated in this testing are significantly higher than those used in conventional filtration. Depending on basis of design, the influent rate possible for the Fuzzy Filter is approximately six to eight times that of conventional filtration.

Tertiary Treatment With Chemical Addition

The Fuzzy Filter demonstrated limited capabilities for phosphorus removal under the conditions tested. Chemical addition was tested for two objectives: to improve particle capture and filter performance, and to remove phosphorus. Two chemicals, polyaluminum chloride (PACl) and

alum, were tested in filtration of secondary effluent. The results of the pilot testing led to the following conclusions:

- PACl was a more effective chemical coagulant than alum under the conditions of the testing.
- Coagulant addition prior to the Fuzzy Filter decreases the average effluent turbidity more than when there is no chemical addition.
- Adequate mixing and reaction time to ensure effective floc formation must be provided upstream of the Fuzzy Filter to achieve optimum total suspended solids (TSS) and phosphorus removal and chemical usage.
- PACl dosage rates of 70 mg/L were required to achieve phosphorus removal to levels established in the performance objectives under the conditions tested. However, coagulant addition at this rate resulted in run times less than two hours, making implementation and reliable performance questionable.
- The reduction of the wash-cycle pressure set point reduced effluent turbidity, but decreased filter run times. In a full-scale facility, effluent turbidity should be used as an additional control parameter to initiate a wash cycle when a set point effluent turbidity is reached.
- The addition of small amounts of coagulant can improve the reliability of the effluent quality with minor reductions in filter run time.

Introduction

The Fuzzy Filter (Fuzzy Filter), manufactured by Schreiber, is one of eight unit processes that were tested during the King County (County) Water Reuse Demonstration Project (Project). The overall objective of the Project was to evaluate emerging wastewater treatment technologies and to determine if the effluent they produce can meet the Washington State Class A reclaimed water standards and/or the more stringent water quality standards associated with other reuse opportunities being considered by the County. During the demonstration project, the Fuzzy Filter was tested for treatment of primary influent and secondary effluent. This document discusses the testing that was performed, test results, and full-scale implementation considerations of the technology.

Description of the Technology

General Filtration Theory

Filtration is commonly used in water and wastewater applications to remove particulate and colloidal matter. In wastewater applications, filters are most often used to remove suspended solids to levels below 10 mg/L. In water reuse applications, the main objective of filtration is turbidity removal. In applications where biological nutrient removal is required, filters can serve two roles: 1) as a polishing step to remove particulate nutrients down to low levels, or 2) as a primary removal mechanism for phosphorus after coagulation.

Filter Types

Conventional filters are categorized by the direction of flow, type of filter used, media, driving force, and method of flow control. The majority of filters found in wastewater applications are down flow gravity filters. Liquid is fed into the top of the filter, and gravity is the primary driving force to pass the through the media. Most filters have granular media, usually consisting of sand or a combination of anthracite and sand to maximize solids capture. Most wastewater filters are the variable-declining-rate type. In variable-declining-rate filters, wastewater is fed to individual filter cells through a common channel. The water level in the filter complex is the same over all of the filters. However, the flow rate through each of the individual filter cells is different, depending on the headloss through each cell.

Particle Removal Mechanisms

There are many mechanisms that influence the ability of a granular media filter to remove and retain solids, but they fall into three main categories: transport, removal, and detachment.

Transport

In order for a filter to remove solids, the solids must be transported into the bed material. Common transport mechanisms in granular filtration include convection (interception), gravity (sedimentation), inertia, and diffusion.

Removal

Once the particle is transported to the filter bed, the particle must be removed from the flow for the filter to be effective. Removal mechanisms include size exclusion (straining or screening) and attachment. Attachment can involve van der Waals forces, electrostatic interactions, and specific adsorption.

Detachment

A mechanism often overlooked in the analysis of filters is detachment. As the filter retains more and more solids, the effective size of the interstitial channels formed by the media is reduced. Therefore, if a constant filtration rate is being used, the velocity through the smaller pore spaces increases. The increased velocity results in an increased shear force on the attached particles. This increase in shear force can cause particles to become detached and move farther into the filter bed or out of the filter.

Use of Coagulants for Improving Filter Performance

Addition of a coagulant or filter aid is often used to enhance particulate removal in a filter. Coagulants are also used when filtration is used for phosphorus removal. Generally, coagulants increase the size of the particulates by destabilizing colloids. Coagulants can also be used to improve surface chemistry of the filter media and improve particle removal.

Influences on Filter Performance

The ability of a filter to remove particulate matter depends on a host of factors, including media size and depth, filtration rate, size and concentration of particulates to be removed, collector size or effective pore size of the media bed, and the solids holding capacity of the filter.

Comparison of Fuzzy Filter to Conventional Filters

The Fuzzy Filter is a relatively new filtration technology that has several unique properties relative to conventional filtration. A comparison of the characteristics of the Fuzzy Filter and conventional filtration is shown in Table 1.

Table 1. Comparison of Conventional Filtration and Fuzzy Filter Properties

Filtration Parameter	Conventional Filtration	Fuzzy Filter
Porosity	Sand – 40 to 46% Anthracite – 50 to 60%	85 to 88% (uncompressed bed)
Media Bed Material	Sand and anthracite	Synthetic spheres made of non-reactive polyvaniladene. Spheres are fibrous and compressible.
Flow in Media Bed	Upflow or Downflow - Because media bed is usually granular, flow is through the pores created by grain to grain contact.	Upflow - Spheres are porous and allow flow through the sphere. Flow occurs through both the pore space created by the spheres and through the spheres.
Filter Loading Rate	3 to 8 gpm/ft ²	10 to 40 gpm/ft ²
Media Property Control	Properties of media are fixed.	Properties of the media can be varied by compressing the media bed..
Backwash water source	Most commonly backwashed with filter effluent.	Usually backwashed using filter influent.

The Fuzzy Filter media bed is composed of compressible, porous, synthetic balls that are 30 mm (1.25 inches) in diameter and have a much higher porosity than conventional filter media. This increases the amount of available solids storage capacity and the hydraulic capacity of the Fuzzy Filter relative to conventional filters. In addition, unlike conventional media, the porous spheres are configured so that flow can occur through the spheres. In conventional filtration, the only spaces available to flow are between the grains of the media. Another innovative characteristic of the Fuzzy Filter is that the filter media can be compressed using a movable top retainer plate. By varying media compression, the porosity and the effective pore size can be adjusted to accommodate different influent characteristics. Because of its unique properties, the Fuzzy Filter has been shown to perform successfully at filter loading rates that are much higher than those of conventional filtration. Conventional filters are normally designed for loading rates from 3 to 8 gpm/ft². The Fuzzy Filter has been shown to perform effectively at loading rates between 10 and 40 gpm/ft².

Based on studies performed by Caliskaner, *et al.* (1999), the primary removal mechanisms for the Fuzzy Filter are interception and straining, both of which are functions of the particle-size to collector-size ratio. The Fuzzy Filter media is synthetic and has very little surface charge. This makes it very easy for the Fuzzy Filter to be cleaned. Because the material is synthetic, the role of surface charge and surface adsorption on the removal of particulate matter from the filter influent is thought to be minor. Therefore, the primary removal mechanisms are physical and not related to chemical properties of the media. Removal of the particles is dependent more on the pore size of the media and the influent particle size.

Findings of Previous Studies

Because the Fuzzy Filter is a rather new technology, there are relatively few studies of its performance. Caliskaner, *et al.* (1999) tested the performance of the Fuzzy Filter with secondary effluent from a conventional activated sludge system. The performance of the Fuzzy Filter was found to be similar to that of conventional filtration technologies, but at hydraulic loading rates that were between three and six times that of conventional filtration. The filter was found to produce effluent with turbidities less than 2 NTU for influent turbidities up to 8 NTU. The researchers also found that the optimum bed compression on the filter was between 15 and 30%. Based on the data gathered during the study, it was concluded that the primary removal mechanisms for the Fuzzy Filter were interception and straining and that performance of the Fuzzy Filter was dependent on the particle size and concentration in the incoming flow.

A Fuzzy Filter was installed in 1998 at a trickling filter – solids contact wastewater plant in Yountville, California. Although initial testing showed significant removals without chemical addition, effluent quality from the Fuzzy Filter deteriorated when influent turbidity increased from the plant's secondary clarifiers. A chemical coagulant was added to the flow going into the filter, and shortly thereafter acceptable performance levels were observed. With chemical addition, the Fuzzy Filter was found to produce effluent with turbidity <2 NTU (Burchett, *et al.*, 2000).

Brown and Wistrom conducted studies on the performance of the Fuzzy Filter while treating primary effluent (1999). The performance of the Fuzzy Filter was compared with two other innovative filtration technologies. Researchers found that the removal of TSS by the Fuzzy Filter ranged from 40 to 65% at hydraulic loading rates 2 to 15 times that of the other technologies. Removal of TSS was found to decrease with increasing loading rates. Researchers also measured the sizes of particulates in the influent to the filters. The removal efficiency of the Fuzzy Filter was found to be greater with larger particle sizes.

Current Installations

A summary of current Fuzzy Filter installations is shown in Table 2.

Table 2. Current Fuzzy Filter Installations

Customer	Location	Date of Operation	No. of Filters	Filter Area (ft ² /unit)	Average Capacity (MGD)	Application
University of CA	Davis, CA	April 1995	1	0.5 square meters.	0.3	Municipal / Experimental
Columbus CSO Facility	Columbus, GA	July 1995	6	64	21	Municipal Stormwater
Bil-Mar Foods / Sara Lee	Zeeland, MI	December 1997	1	49	2.2	Industrial
Yountville Sanitary Dist.	Yountville, CA	May 1998	1	25	0.6	Municipal
Butterball / ConAgra	Wallace, NC	June 1998	2	16	1.5	Industrial
Golden Poultry / Gold Kist	Sanford, NC	July 1998	1	36	1.5	Industrial
La Caldera WTP	Tecodesa, Mexico City	Spring 2000	1	49	1.4	Municipal
Purisima I WTP	Tecodesa, Mexico City	Spring 2000	1	49	1.4	Municipal
San Lorenzo WWTF	Tecodesa, Mexico City	Fall 2000	3	49	1.9	Municipal
Orange Co. San. Dist.	Fountain Valley, CA	Summer 2001	1	64	3.2	Municipal
Farbest Foods, Inc.	Indiana	Summer 2001	1	25	1.0	Industrial
Clayton Co. Northeast WPCF	Georgia	October 2001	5	49	15	Municipal
Logan-Todd	Kentucky	Under Const.	2	36	2.0	Municipal
Malaga	California	March 2002	1	9	0.4	Municipal
Rogersville	Missouri	Under Const.	2	25	0.5	Municipal

General Operation

A general schematic of the Fuzzy Filter system during both the filtration and wash cycles is shown in Figure 1. During filtration, influent enters the bottom of the filter and travels upward through the media bed. The media consists of porous, compressible, synthetic-fiber balls that are 30 mm (1.25 inches) in diameter. The media bed is supported on the bottom by a fixed

retainer plate located above an influent plenum. On the top of the filter, the media bed is contained by a movable retainer plate. Both retainer plates have uniformly distributed holes to promote equal distribution of flow. The position of the top retainer plate can be changed by a motor and threaded shaft mounted to the top of the filter. By adjusting the position of the upper plate, the bed compression can be varied, depending on performance requirements.

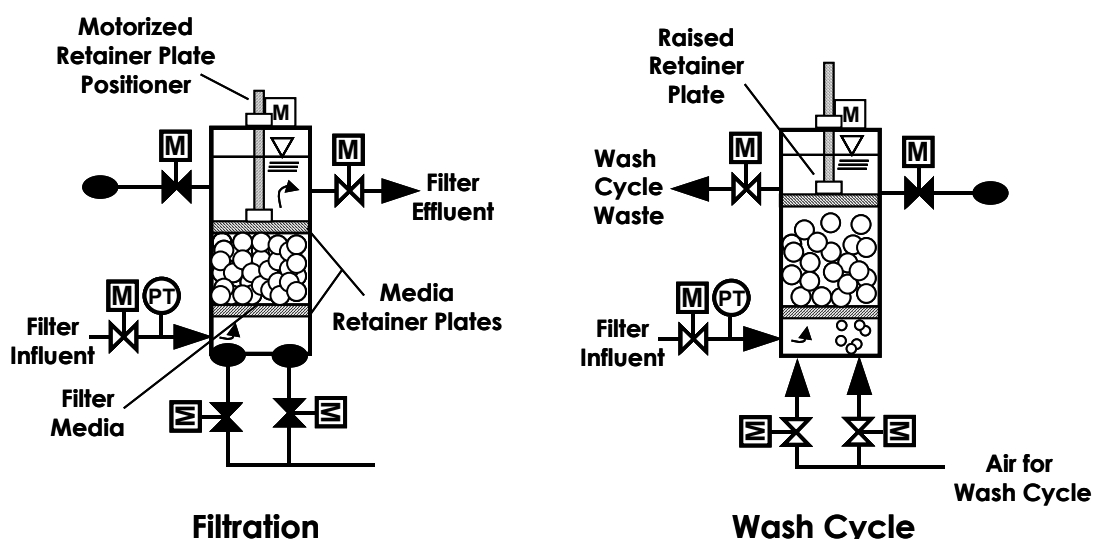


Figure 1. Fuzzy Filter General Operation Schematic

As influent flows through the media, suspended solids are captured and retained in the filter bed. As more and more solids are removed from the influent flow, the retained solids and the resulting headloss across the filter bed increases. Under ideal conditions, solids are captured throughout the entire bed depth, distributing the solids storage through the entire bed. The filter is automatically washed when a filter influent pressure set point is reached, or when the prescribed time from the last wash cycle is reached. The generally recommended trigger for the wash cycle is a pressure set point equivalent to a 48-inch water column (~ 1.75 psi) above the filter influent pressure, just after a wash cycle. This wash cycle pressure set point can be adjusted within practical limits to match the operational condition where solids breakthrough will occur. The available head and the strength of the retainer plate and associated adjustment shafts control the maximum allowable filter influent pressure prior to a wash cycle.

During the wash cycle, the effluent line is closed and the waste line is open. The top retainer plate is then raised to allow free movement of the filter media. The media is washed using a combination of filter influent and air. Filter influent is used to flush solids from the media, and is generally supplied at a rate of 10 gpm/ft^2 . To scour the media, air is supplied to the bottom of the filter at a rate of 15 cfm/sf of media through two headers, located at opposite sides of the

filter. The automatic wash cycle consists of a total of seven stages, normally two to five minutes each in duration. A summary of the seven stages used for the wash cycle is shown in Table 3.

Table 3. Wash Cycle Stages

Wash Cycle Stage	Description
1	Air is supplied from one of two headers to produce counterclockwise rotation of the bed.
2	Air is supplied from second header to produce clockwise rotation of the bed.
3	Air supplied to both headers.
4	Repeat Stage 1.
5	Repeat Stage 2.
6	Repeat Stage 3.
7	Compression plate is moved to the position it had before backwash. Filter to waste drain remains open during the entire stage and effluent valve remains closed.
Notes: Air is supplied to the filter at a rate of 15 cfm/ft ² during the first six wash stages. No air is supplied during Stage 7. Influent is supplied to the filter at a rate of 10 gpm/ft ² during all wash stages.	

The first six stages of the wash cycle are intended to loosen all retained solids accumulated during the filter run and remove them through the wash cycle waste line. During the last stage, the media compression plate is moved back to the pre-wash position (or to a position selected to change the performance of the filter), and the remaining solids are purged from the filter through the waste line. After the purge cycle, the influent flow rate is changed to the normal filter rate, the effluent valve is opened, the waste valve is closed, and the filter is returned to service.

Pilot Testing

Goals and Objectives

The goals and objectives established by the Project Team for the Fuzzy Filter testing for both primary and tertiary applications is shown in Table 4.

Table 4. Summary of Pilot Testing Objectives

Key Performance Questions	Performance Goals
Primary Application without Chemical Addition	
<ul style="list-style-type: none"> Ability of system to operate when receiving raw wastewater. Tendency of filter to plug. Ability to remove solids – effluent quality at various periods during filter run. Potential for long-term accumulation of solids in media (fouling). Length of filter runs and ratio of backwash volume to treated volume. Wash cycle sequencing to regain full use of bed. Upper limit of solids loading. 	<ul style="list-style-type: none"> Filter run times > 24 hours. >80% TSS removal. Wash cycle waste <8% of treated flow. Zero long-term buildup of clean bed headloss.
Primary Application with Chemical Addition	
<ul style="list-style-type: none"> Ability to remove phosphorus. Improvement in TSS and BOD removal when alum is used. Impact of alum addition on run time, fouling potential, wash cycle requirements. Impact of alum addition on solids loading capacity. Optimal alum dosage. 	<ul style="list-style-type: none"> Filter run times > 12 hours. >80% TSS removal. >80% t-P removal with alum. Wash cycle waste <8% of treated flow. Zero long-term buildup of clean bed headloss.
Tertiary Application with and without Chemical Addition	
<ul style="list-style-type: none"> Tendency of filter to plug. Ability to remove solids – effluent quality at various periods during filter run. Potential for long-term accumulation of solids in media (fouling). Length of filter runs and ratio of backwash volume to treated volume. Wash cycle sequencing to regain full use of bed. Upper limit of solids loading. Impact of coagulant addition on run time, fouling potential, and wash cycle requirements. 	<ul style="list-style-type: none"> Effluent TSS < 5 mg/L, 90th percentile. Effluent turbidity < 2 NTU, 90th percentile. Effluent t-P concentrations < 0.5 mg/L, 90th percentile. Compliance with Washington State Class A reclaimed water requirements. Filter run times > 24 hours. Wash cycle waste <8% of treated flow. Less than 2% long-term increase in clean bed headloss per year.

Description and Graphic Presentation of the Demonstration Setup

General

Pilot Unit Components

A picture of the Fuzzy Filter experimental pilot setup is shown in Figure 2. The specific components of the Fuzzy Filter pilot unit supplied by the manufacturer are summarized in Table 5.



Figure 2. Photograph of Fuzzy Filter Experimental Setup

Table 5. Specific Components of the Fuzzy Filter Pilot Unit

Component	Pilot Unit
Filter Unit	Filter area: 2 ft x 2 ft (4 ft ² total area). Filter media depth: 35 inches. Static water depth from influent to outlet piping: 6 ft
Filter Wash Blowers	60 cfm rated capacity; one provided.
Control and Isolation Valves	Filter influent: None provided by vendor. 4" facility side ball valve. Effluent isolation valve: 4" butterfly valve. Filter to waste valve: 4" butterfly valve. Air header valves: 3" butterfly. All valves electrically actuated.
Top Retainer Plate	Threaded stainless steel shaft with motorized positioner.
PLC	PLC provided with operator interface screens for manual and automatic control of all components.

Primary Treatment Pilot Operation

A schematic of the pilot unit setup for primary treatment testing is shown in Figure 3.

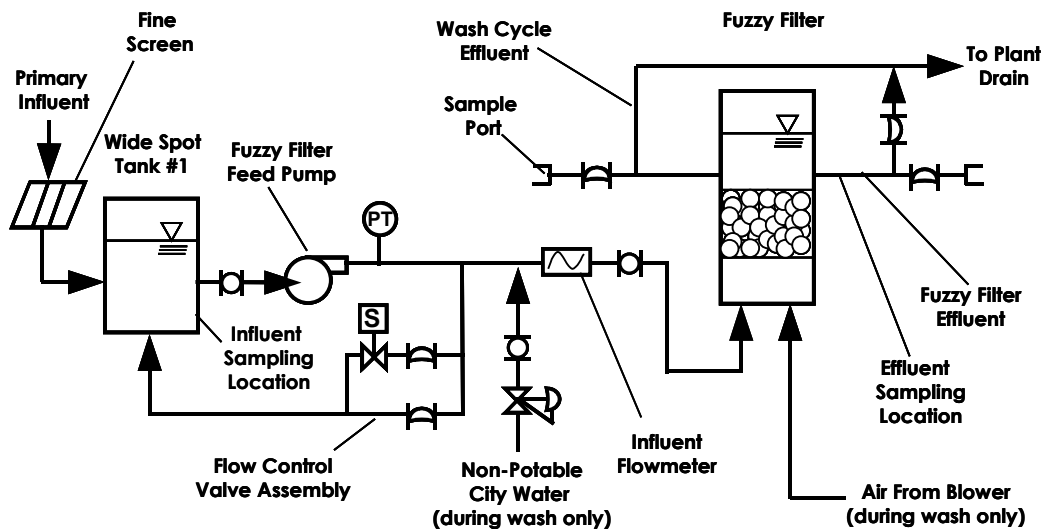


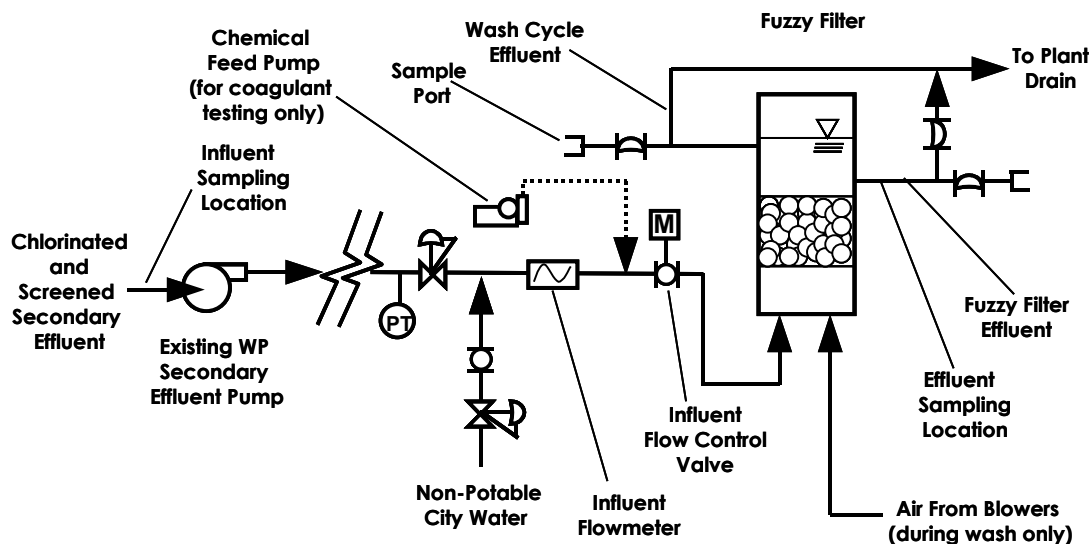
Figure 3. Schematic of Primary Fuzzy Filter Experimental Setup

During primary treatment testing, primary influent (bar-screened and de-gritted sewage) from the West Point WWTP was supplied to the Fuzzy Filter pilot unit. Primary influent was pumped from the influent end of a West Point primary sedimentation tank using a pump installed for the pilot testing. Once at the pilot test facility, primary influent was screened through a fine screen with 6 mm openings and then discharged to Wide Spot Tank #1. Flow was then pumped from Wide Spot Tank #1 to the Fuzzy Filter. During the primary testing, a flow control assembly allowed the operations team to manually vary the amount of flow to the Fuzzy Filter. Influent and effluent samples during primary testing were taken from Wide Spot Tank #1 and the Fuzzy Filter effluent line, respectively.

During automated wash cycles of the Fuzzy Filter, the influent feed pump was stopped and city-supplied water was fed to the filter for wash cycles. An influent ball valve was used to throttle wash cycle water flow. A blower supplied by the Fuzzy Filter manufacture was used to provide air for media scour.

Tertiary Treatment Pilot Operation

A schematic of the tertiary testing pilot setup is shown in Figure 4.



NOTE: Approximately 100 ft of additional 4" feed line was added between influent flow control valve and Fuzzy Filter on 2/15/02

Figure 4. Schematic of Tertiary Fuzzy Filter Experimental Setup

After completion of primary testing, the Fuzzy Filter pilot unit was reconfigured to test its performance in the treatment of screened secondary effluent from the West Point WWTP. Existing plant pumps located in the chlorine contact channel were used to convey secondary effluent to the pilot facility location. Prior to being pumped to the test facility, secondary clarifier effluent passed through a 1/16"-opening fine screen and was chlorinated. The lag time between the clarifiers and the experimental location was approximately one hour due primarily to travel time between the secondary clarifier and the pumping location.

Line pressure was reduced at the test facility with a pressure-reducing valve. After reduction of pressure, flow was fed directly to the pilot unit through a flow-control ball valve. The ball valve was automatically controlled to maintain a consistent flow to the Fuzzy Filter pilot unit. Wash water for tertiary filtration was filter influent (secondary effluent). Wash water was applied at a constant rate of 10 gpm/ft² (40 gpm) and was controlled through the facility PLC and flow-control ball valve.

During the testing of the filter with the addition of coagulants, coagulant was fed using a diaphragm-metering pump upstream of the Fuzzy Filter. No external mixing device was used at the point of injection. Approximately one minute of reaction time was available between the coagulant injection point and the Fuzzy Filter. After the initial test results for addition of coagulant were examined, a 100-foot section of 4-inch flexible hose was installed immediately upstream of the filter and downstream of the chemical injection location. The flexible hose provided an additional minute of coagulant reaction time prior to the filter (two minutes total). Addition of the flexible feed hose was completed on February 15, 2002.

Between primary testing and tertiary testing with no chemical addition, and again between tertiary testing with no chemical addition and tertiary testing with chemical addition, the fuzzy Filter was cleaned using the manufacturer's recommended quarterly cleaning procedures. The purpose of the cleaning was to ensure that no buildup of residuals occurred within the media and to ensure that no results were influenced by previous testing. The cleaning procedure included draining of the filter and then backwashing and soaking the media with hypochlorite for a period of three hours. The detailed cleaning procedure provided by the Fuzzy Filter manufacturer and used during the pilot testing is included in Appendix A.

Comparison of Pilot Unit to Full-Scale Application

The components of a full-scale system would be similar to the components used during the pilot testing. The components of the pilot testing unit and a comparison to a full-scale application are summarized in Table 6.

Table 6. Comparison of Pilot and Full-Scale Application of Fuzzy Filter

Component	Pilot Unit	Full-Scale Application
Filter Unit	Filter Area: 2 ft x 2 ft (4 ft ² total area). Filter Media Depth: 35 inches.	Sizes range from 2.25 ft ² to 64 ft ² . Area and media depth depend on design criteria and number of units desired.
Filter Wash Blowers	60 cfm rated capacity; one provided..	Size and rating depend on application. All designed to provide 15 cfm/ft ² .
Control and Isolation Valves	Filter influent: None provided. 4" facility side ball valve. Effluent isolation valve: 4" butterfly valve. Filter to Waste valve: 4" butterfly valve. Air header valves: 3" butterfly valve. All valves electrically actuated.	Size depends on flow rate. Valves on full-scale application also electrically actuated.
Top Retainer Plate	Threaded stainless steel shaft with motorized positioner.	Threaded stainless steel shaft with motorized positioner. Reinforcement depends on size and expected stresses.
PLC	PLC provided with operator interface screens for manual and automatic control of all components.	PLC provided in full scale will provide same functionality as in pilot tests. Specific details depend on full-scale application.

Testing Plan

Test Conditions

The original testing plan called for four phases of testing as shown in Table 7. A complete summary of the original testing plan is included in Appendix A.

Table 7. Summary of Initial Fuzzy Filter Testing Plan

Testing Phase	Summary of Testing	Original Schedule
Primary without Chemical Addition	Weeks 1-3: Operation Parameter Evaluation Week 4: Extended Operation	October 2001
Primary with Chemical Addition	Weeks 1-3: Coagulant Testing/Optimization Week 4: Extended Operation	November 2001
Tertiary with Chemical Addition	Weeks 1-6: Coagulant Testing/Optimization Week 7-8: Extended Operation	December 2001 – January 2002
Tertiary without Chemical Addition	Weeks 1-3 Operation Parameter Evaluation	February 2002

During testing, the actual conditions tested and the phases of testing that were carried out were modified to address changes in schedule, operational issues that arose, and observations made during the initial phases of testing. Filter run results were reviewed frequently and modifications were made to the testing plan and apparatus as needed during each testing period. Table 8 summarizes the actual testing performed on the Fuzzy Filter under each phase during the pilot study.

Table 8. Overview of Testing Performed with Fuzzy Filter During Pilot Project

Testing Phase	Testing Summary	Operational Conditions Tested	Date of Testing
Primary without Chemical Addition	Operational Condition Testing	HLR: 5-25 gpm/ft ² Bed Compression: 5-30%	October 2001 through November 2001 ^a
Tertiary without Chemical Addition	Operational Condition Testing	HLR: 10-40 gpm/ft ² Bed Compression: 10-30%	December 2001 January 2002
	Extended Operations Testing	HLR: 30 gpm/ft ² Bed Compression: 20%	January 2002 ^b
Tertiary with Chemical Addition	Operational Condition Testing	HLR: 10-30 gpm/ft ² Bed Compression: 10-30% Coagulants / Dosages: Alum: 30 mg/L and 75 mg/L Polyaluminum Chloride: 15-70 mg/L	February 2002 March 2002

NOTES:

a. Testing 12/04-12/06 performed to troubleshoot Fuzzy Filter under primary influent feed conditions.

b. Additional extended operations testing was performed 3/15/02 through 3/18/02.

During operational condition testing, the filter was operated under different hydraulic loading rates and different bed compressions. The purpose of this testing was to identify the optimal operating conditions needed to achieve the objectives of the project.

The purpose of the extended period of testing was to evaluate the performance of the filter over a longer period of operation and to assess the stability of the process under varying influent conditions. Conditions for extended testing were chosen based on observed results in the operational condition testing period. Conditions resulting in the highest throughput while meeting Project effluent objectives were used in the extended testing.

Operation of Pilot Unit During Testing

In general, the pilot unit was operated similarly during both primary and tertiary testing. During the operational conditions testing, the test duration for each condition was approximately 24 hours. At the beginning of each new test period, the filter was manually washed to clean solids from the previous run. After washing, the new test conditions were set by operations staff. Most often, changes were made to the hydraulic loading rate (influent flow rate) and to the degree of bed compression applied to the media. The influent flow rate to the Fuzzy Filter was set manually during primary testing (see Demonstration Setup Section). After installation of the automated control valve, the influent flow rate was set and automatically controlled via the facility PLC. Bed compression was set through the pilot unit PLC, which positioned the movable retainer plate to achieve a desired depth of media. The depth was verified by physically measuring the position of the retainer plate relative to the bottom of the filter bed.

The clean bed filter influent pressure was determined from readings of the pressure transmitter at the influent of the Fuzzy Filter. Normal values of clean bed filter influent pressure ranged from 2.8 to 4 psi during testing. The clean bed filter influent pressure combined both pressure due to static water level between influent and effluent (~ 6 ft) and filter media headloss at the beginning of a filter run. After determining the clean bed filter influent pressure, the wash cycle pressure set point was entered into the pilot unit PLC. Usually the pressure set point was set at 1.75 psi above the observed clean bed filter influent pressure.

After the operational parameters were established at the Fuzzy Filter, the pilot unit was allowed to operate in automatic mode for the duration of the testing period. Backwashes were triggered automatically and were controlled by the pilot unit PLC. Composite samplers were reset at the beginning of each filter run to isolate samples for each testing condition.

Table 9 summarizes the operational parameters used during the pilot testing and changes made during the testing periods.

Table 9. Range of Operational Parameters Tested During Pilot Study

Operational Parameter	Operating Range or Value Used for Testing	Changes Made During Testing
Influent Feed Rate / Filter Loading Rate	See Table 8	Loading rate varied during all phases of testing.
Media Bed Compression	See Table 8	Bed compression varied during all phases of testing.
Wash Cycle Duration	2.5 minutes per stage for first six stages. 5 minutes for last stage (purge stage).	No changes made during testing.
Wash Cycle Influent Flow Rate	10 gpm/ft ² (40 gpm total)	No changes made during testing.
Air Scour Flow Rate During Wash Cycle	15 cfm/ft ² (60 cfm total)	No changes made during testing.
Wash Cycle Pressure Trip Point	1.75 psi above clean bed headloss	Primary Testing: no changes made. Tertiary Testing: Wash cycle pressure set point was set at 4 psi in response to excursions above 2 NTU during late stages of filter runs.

Sampling and Analysis

During each test condition, parameters were monitored on a daily basis. Monitoring, sampling, and associated analysis performed during the Fuzzy Filter pilot testing are summarized in Table 10.

Table 10. Summary of Fuzzy Filter Sampling, Analysis, and Monitoring

Parameter	Location of Sample	Sample Type and Frequency	Method of Analysis / Monitoring
CODt, TSS, VSS	Influent and Effluent	Daily composite – sample taken daily during pilot unit operation.	West Point Laboratory
BODt, BODs, t-P, PO ₄ , NH ₃	Influent and Effluent	Daily composite - Sample frequency varied over pilot testing. Primary: bi-weekly Tertiary - no chemical: weekly Tertiary with chemical: daily	West Point Laboratory
Turbidity	Influent and Effluent	Primary Testing: Effluent Only – Continuous Tertiary Testing: Influent – Continuous readings taken from secondary clarifier effluent turbidimeter at WP Plant. Effluent – Continuous readings taken from pilot project effluent turbidimeter	Primary Testing: Effluent – data sent to pilot PLC. Tertiary Testing: Influent: WP data downloaded from plant PLC Effluent: data sent to pilot PLC.
Filter Influent Pressure (psi)	Influent	Continuous	Pressure transmitter mounted on Fuzzy Filter skid at base of unit signal sent to facility PLC.
Filter Influent Feed Rate (gpm)	Influent	Continuous	Flow meter on feed line to Fuzzy Filter; data recorded by PLC.
WP Plant Flow (MGD) (tertiary testing only)	NA	Continuous	WP data downloaded from plant PLC.

Fuzzy Filter effluent turbidity for both phases of testing was monitored continuously using a HACH 1720D turbidimeter. Composite samples were taken using ISCO type 2910 autosamplers. The autosamplers were set to collect samples every hour. All analysis performed by the West Point Laboratory were according to standard methods. A complete summary of laboratory results for samples taken for each testing condition is included in Appendix E.

Secondary effluent turbidity data recorded at the West Point WWTP was used as the influent turbidity data for the tertiary testing. After measurement of turbidity, the secondary effluent was chlorinated and screened (1/16-inch opening size) prior to being fed to the Fuzzy Filter. The lag time between turbidity measurement and feed to the pilot testing facility was estimated to be one hour. The lag time was due primarily to detention time in the plant chlorine contact

tank. To account for the lag time, one hour was added to the recorded turbidity measurement time prior to analysis. During West Point plant bypass events, the turbidity measurements taken at the plant were not representative of the influent to the Fuzzy Filter (see further discussion in Tertiary Testing with No Chemical Addition section).

Primary Treatment

The Fuzzy Filter was tested in treatment of screened and de-gritted primary influent from the West Point WWTP from October through November 2001. The Fuzzy Filter was operated with hydraulic loading rates ranging from 5 to 30 gpm/ft² and bed compressions ranging from 0 to 30%. Test conditions, dates of testing, and testing comments are shown in Table 11.

Table 11. Summary of Test Conditions During Primary Testing

Start Date	End Date	Hydraulic Loading Rate (gpm/ft ²)	Bed Compression (%)	Wash Cycle Criteria	Testing Comments
10/16/01	10/17/01	5	5	Time - 3 hours	High flow to WP plant during beginning of testing; Likely diluted incoming turbidity. Turbidimeter functioning during testing.
10/17/01	10/18/01	5	15	Time - 3 hours	Turbidimeter functioning during testing.
10/18/01	10/19/01	5	20	Time - 3 hours	Flow lost to turbidimeter.
10/19/01	10/20/01	5	20	Time - 3 hours	Flow lost to turbidimeter.
10/20/01	10/21/02	5	20	Time - 3 hours	Flow lost to turbidimeter.
10/21/01	10/22/01	5	20	Time - 3 hours	Flow lost to turbidimeter.
10/22/01	10/23/01	5	25	Time - 3 hours	Flow lost to turbidimeter.
10/23/01	10/24/01	5	25	Time - 3 hours	Turbidimeter functioning for two filter runs; flow lost to turbidimeter after first two runs.
10/24/01	10/25/01	5	30	Time - 3 hours	Flow lost to turbidimeter.
10/25/01	10/26/01	5	30	Time - 3 hours	Flow lost to turbidimeter; flow re-established during last two runs.
10/28/01	10/29/01	5	10	Influent Pressure	Flow lost to turbidimeter.
10/29/01	10/30/01	10	10	Influent Pressure	Flow lost to turbidimeter.
10/30/01	10/31/01	15	12.5	Influent Pressure	Flow lost to turbidimeter.
10/31/01	11/1/01	15	12.5	Influent Pressure	Flow lost to turbidimeter.
11/1/01	11/2/01	10	20	Influent Pressure	Flow lost to turbidimeter.
11/5/01	11/6/01	10	20	Influent Pressure	Intermittent flow to pilot unit; flow lost to turbidimeter.
11/6/01	11/7/01	10	20	Influent Pressure	Flow lost to turbidimeter.
11/7/01	11/8/01	15	20	Influent Pressure	Intermittent flow to pilot unit; flow lost to turbidimeter.
11/8/01	11/9/01	15	20	Influent Pressure	Intermittent flow to pilot unit; flow lost to turbidimeter.
11/12/01	11/12/01	15	20	Influent Pressure	Replumbed effluent turbidimeter and composite sample bucket location.
11/13/01	11/14/01	10	30	Influent Pressure	High flow to WP plant during this trial; likely diluted incoming turbidity.
11/14/01	11/15/01	15	30	Influent Pressure	High flow to WP plant during this trial; likely diluted incoming turbidity.
11/15/01	11/16/01	18	30	Influent Pressure	High flow to WP plant during beginning of test; likely diluted incoming turbidity; Lost flow to turbidimeter during later stages of testing.
11/19/01	11/20/01	20	30	Influent Pressure	High flow to WP plant during testing; likely diluted incoming turbidity; Turbidimeter functioning during initial portion of test; lost flow in later stages of test.
11/20/01	11/20/01	20	30	Influent Pressure	Short test; turbidimeter functioning during testing.
12/4/01	12/5/01	22.5	20	Influent Pressure	Turbidimeter functioning; Steep increase in WP plant

Start Date	End Date	Hydraulic Loading Rate (gpm/ft ²)	Bed Compression (%)	Wash Cycle Criteria	Testing Comments
					flow may have diluted incoming turbidity.
12/5/01	12/5/01	15	20	Influent Pressure	Short test: Grab turbidity readings taken of influent and effluent.
12/5/01	12/5/01	15	27	Influent Pressure	Short test: Grab turbidity readings taken of influent and effluent.
12/5/01	12/5/01	15	0	Influent Pressure	Short test: Grab turbidity readings taken of influent and effluent.

During the initial stages of testing, the Fuzzy Filter was backwashed every three hours. After October 28, 2001, the Fuzzy Filter was run in automatic mode, with wash cycles triggered based on the build-up of filter influent pressure. As can be seen from Table 11, it was difficult to maintain flow to the turbidimeter, likely because of the large amount of solids in the liquid to be sampled. On November 12, 2001, the turbidimeter was relocated to take samples from the sample bucket used for composite sampling. Prior to this time, the turbidimeter tap was located in the top of the line coming from the Fuzzy Filter. At times, particularly during backwash, the pipe was not completely full, interrupting flow to the turbidimeter. After relocation, more reliable operation of the turbidimeter was observed, although there were still periods when accurate measurements were not obtained.

During the testing of the Fuzzy Filter in a primary application, short-circuiting of flow along the walls of the filter was observed with very little increase in the filter influent pressure. On December 4, 2001, and December 5, 2001, short-term testing was performed to investigate this phenomenon. During the short duration tests, operations personnel took grab samples for influent and effluent turbidity shortly after wash cycles. Samples were taken for several minutes. Results of this short-term testing are discussed in the Results section. Graphs from this testing are included in Appendix B.

Tertiary Treatment With No Chemical Addition

During tertiary testing without chemical addition, the Fuzzy Filter was operated with hydraulic loading rates ranging from 10 to 40 gpm/ft² and bed compressions ranging from 10 to 30%. Testing performed on the Fuzzy Filter in treatment of secondary effluent without chemical addition is summarized in Table 12.

Table 12. Test Conditions for Tertiary Testing With No Chemical Addition

Test Condition Number	Start Date	End Date	Avg. Influent Turbidity (NTU)	Hydraulic Loading Rate (gpm/ft ²)	Bed Comp. (%)	Backwash Criteria	Testing Comments
1	12/5/01	12/6/01	2.6	22.5	30	1.75 psi above CBP	
2	12/19/01	12/20/01	2.5	20	20	1.75 psi above CBP	
3	12/26/01	12/27/01	1.4	20	20	1.75 psi above CBP	
4	12/30/01	12/31/01	1.9	10	20	1.75 psi above CBP	
5	12/31/01	1/1/02	1.8	30	20	1.75 psi above CBP	
6	1/1/02	1/2/02	3.1	30	20	1.75 psi above CBP	Primary effluent bypass during test
7	1/2/02	1/3/02	1.3	20	30	1.75 psi above CBP	
8	1/3/02	1/5/02	1.8	10	30	1.75 psi above CBP	
9	1/5/02	1/7/02	3.7	30	30	1.75 psi above CBP	Primary effluent bypass during test
10	1/7/02	1/8/02	2.9	30	30	1.75 psi above CBP	Primary effluent bypass during test
11	1/8/02	1/9/02	2.4	30	10	1.75 psi above CBP	
12	1/9/02	1/10/02	1.4	10	10	1.75 psi above CBP	
13	1/10/02	1/13/02	2.4	30	30	1.75 psi above CBP	
14	1/13/02	1/14/02	2.8	32.5	10	1.75 psi above CBP	
15	1/14/02	1/15/02	3.0	40	10	1.75 psi above CBP	
16	1/15/02	1/16/02	3.6	40	30	1.75 psi above CBP	
17	1/16/02	1/18/02	2.6	40	20	1.75 psi above CBP	
18	1/18/02	1/23/02	2.6	40	30	1.75 psi above CBP	
19	1/23/02	1/31/02	5.4	30	20	1.75 psi above CBP	Extended testing; primary effluent bypass during test
28	2/13/02	2/14/02	12.6	10	20	1.75 psi above CBP	
29	2/14/02	2/15/02	9.1	30	20	1.75 psi above CBP	
30	2/15/02	2/18/02	6.5	30	20	1.75 psi above CBP	
41	3/12/02	3/13/02	5.2	25	10	4 psi (total)	
44	3/15/02	3/18/02	4.4	30	20	4 psi (total)	Extended testing

Notes:

CBP = Clean bed filter influent pressure.

Average influent turbidities shown during bypass do not include contribution from primary effluent.

The test condition numbers shown in Table 12 were used to keep track of different test conditions used during the Fuzzy Filter testing in a tertiary application. The graphs shown in Appendix C for each filter run are labeled with the same test condition numbers. During the majority of the testing in a tertiary application with no chemical addition, the wash cycle pressure set point was established at 1.75 psi above the clean bed filter influent pressure (CBP).

Occurrences of primary effluent bypass at the West Point WWTP are also noted in Table 12. In most cases, the influent to the Fuzzy Filter during the tertiary testing consisted of screened and chlorinated secondary clarifier effluent from the plant. However, under conditions of high flow, primary effluent flows in excess of 300 mgd are bypassed around the secondary treatment

system at the plant and combined with secondary effluent prior to disinfection. The combination point is downstream of the turbidimeter that was used to determine influent turbidity to the Fuzzy Filter. Therefore, in Table 12, the average influent turbidities shown during test conditions when primary effluent bypass occurred do not include turbidity from the primary effluent flow. The performance of the Fuzzy Filter under conditions of primary effluent bypass will be discussed in more detail in the Filter Performance Under Special Conditions section.

The filter influent pressure was monitored using a pressure transmitter on the influent side of the Fuzzy Filter. During primary testing, it was discovered that the pressure readings recorded to the PLC were being truncated prior to being saved in the database. Pressure readings were truncated to the nearest psi. Therefore, small changes in the bed pressure were not shown in the PLC data. The truncation of pressure readings was corrected on January 2, 2002.

Tertiary Testing With Chemical Addition

After completion of testing of the Fuzzy Filter under tertiary conditions, the Fuzzy Filter was tested in the treatment of secondary effluent with the addition of coagulant. During this testing, the Fuzzy Filter was operated at hydraulic loading rates ranging from 10 to 30 gpm/ft² and bed compressions ranging from 10 to 30%. Testing performed during this phase is summarized in Table 13.

Table 13. Test Conditions for Tertiary Testing with Chemical Addition

Test Condition Number	Start Date	End Date	Avg. Influent Turbidity (NTU)	Hydraulic Loading Rate (gpm/ft ²)	Bed Comp. (%)	Backwash Criteria	Coagulant Addition	Testing Notes
20	1/31/02	2/5/02	4.1	20	20	1.75 psi above CBP	Alum - 30 mg/L	
21	2/5/02	2/6/02	5.6	30	20	1.75 psi above CBP	Alum - 30 mg/L	
22	2/6/02	2/7/02	5.4	10	20	1.75 psi above CBP	Alum - 30 mg/L	Primary bypass during trial
23	2/7/02	2/8/02	4.3	20	30	1.75 psi above CBP	Alum - 30 mg/L	Primary bypass during trial
24	2/8/02	2/10/02	2.2	20	20	1.75 psi above CBP	Alum - 30 mg/L	
25	2/10/02	2/11/02	4.2	30	20	1.75 psi above CBP	Alum - 30 mg/L	Primary bypass during trial
26	2/11/02	2/12/02	9.8	20	20	1.75 psi above CBP	Alum - 75 mg/L	
27	2/12/02	2/13/02	14.2	10	20	1.75 psi above CBP	Alum - 30 mg/L	
31	2/18/02	2/19/02	7.0	20	20	1.75 psi above CBP	Alum - 30 mg/L	
32	2/19/02	2/20/02	6.4	10	20	1.75 psi above CBP	Alum - 30 mg/L	
33	2/20/02	2/22/02	11.1	20	20	1.75 psi above CBP	PACI - 30 mg/L	Primary bypass during trial
34	2/22/02	2/26/02	5.2	10	20	4 psi	PACI - 30 mg/L	Primary bypass during trial
35	2/26/02	3/1/02	4.6	10	10	4 psi	PACI - 30 mg/L	
36	3/1/02	3/4/02	3.8	15	20	4 psi	PACI - 30 mg/L	
37	3/4/02	3/5/02	4.3	20	20	4 psi	PACI - 30 mg/L	
38	3/5/02	3/6/02	4.1	20	10	4 psi	PACI - 30 mg/L	
39	3/6/02	3/8/02	3.3	15	10	4 psi	PACI - 30 mg/L	
40	3/8/02	3/12/02	5.3	25	10	4 psi	PACI - 30 mg/L	Primary bypass during trial
42	3/13/02	3/14/02	4.6	30	10	4 psi	PACI - 30 mg/L	
43	3/14/02	3/15/02	4.3	30	10	4 psi	PACI - 15 mg/L	
45	3/18/02	3/20/02	3.6	30	10	4 psi	PACI - 15 mg/L	
46	3/20/02	3/21/02	3.3	30	10	4 psi	PACI - 70 mg/L	
47	3/21/02	3/22/02	3.2	30	10	5 psi	PACI - 50 mg/L	

Test Condition Number	Start Date	End Date	Avg. Influent Turbidity (NTU)	Hydraulic Loading Rate (gpm/ft ²)	Bed Comp. (%)	Backwash Criteria	Coagulant Addition	Testing Notes
48	3/22/02	3/23/02	3.6	20	10	5 psi	PACl - 50 mg/L	
49	3/23/02	3/24/02	3.1	20	10	5 psi	Alum - 70 mg/L	
50	3/24/02	3/25/02	3.3	25	10	5.5 psi	PACl - 70 mg/L	

Notes:

CBP = Clean bed filter influent pressure.

Average influent turbidities measured before addition of coagulant.

Average influent turbidities shown for test conditions during which bypass occurred do not include contribution from primary effluent.

As can be seen in Table 13, there were many different conditions and chemical coagulant types and doses tested. Initially, testing was performed with alum as the chosen coagulant. Jar tests were performed with alum to establish initial dosages for testing. During the initial testing, operations staff observed floc forming in the filter effluent sample bucket, suggesting that flocculation was incomplete prior to filtration. To increase the reaction time prior to the filter and thereby improve the flocculation, an additional hose was added to the influent piping to the Fuzzy Filter (see Pilot Testing section). After observations made during further runs continued to suggest incomplete flocculation, the coagulant was changed to polyaluminum chloride (PACl). PACl addition started on February 20, 2002. Because PACl is partially hydrolyzed, it was reasoned that less reaction time would be required to achieve effective flocculation prior to the filter. The chemical addition rate was varied after this change on various occasions to evaluate the coagulant effect on filter performance and phosphorus removal.

Results

This section contains the results of pilot testing of the Fuzzy Filter in the treatment of primary influent and secondary effluent. Information in addition to the results presented herein is contained in the Appendices. The Appendices and the information contained in each are summarized in Table 14

Table 14. List of Appendices

Appendix	Appendix Contents
A	Test Plan and Filter Cleaning Procedures
B	Primary Treatment Graphs
C	Tertiary Treatment with No Chemical Addition Graphs
D	Tertiary Treatment with Chemical Addition Graphs
E	Laboratory Data
F	Operator Notes
G	Pilot Photos

Primary Treatment

Turbidity Removal

The Fuzzy Filter was tested for approximately six weeks in the treatment of primary influent without the use of chemical coagulants. Gathering data during primary testing was hampered by difficulties with the operation of the effluent turbidimeter due to its location and to high levels of solids in the filter effluent. During primary testing, the influent turbidity to the filter was not monitored. Intermittent primary influent turbidity data from December 3, 2001, through February 15, 2002, for the Densadeg pilot unit was reviewed to determine approximate primary influent turbidity characteristics (see Table 15.)

Table 15. Primary Influent Turbidities Measured during December 2001 and February 2002 for the Densadeg Pilot Unit

Parameter	Turbidity (NTU)
Average	81
Minimum	18
Maximum	192
std deviation	27
10 th percentile	46
50 th percentile	82
90 th percentile	114

Based on the values in Table 15, average primary influent turbidity to the Densadeg pilot unit was approximately 80 NTU, with variations between 46 and 114 NTU under most cases. The turbidity values shown in the table were not taken from the same time period as primary testing of the Fuzzy Filter. However, the data can be used as an estimate of the range of influent turbidities to the Fuzzy Filter during that time.

A typical graph of recorded data taken during a period when the turbidimeter was not functioning is shown in Figure 5.

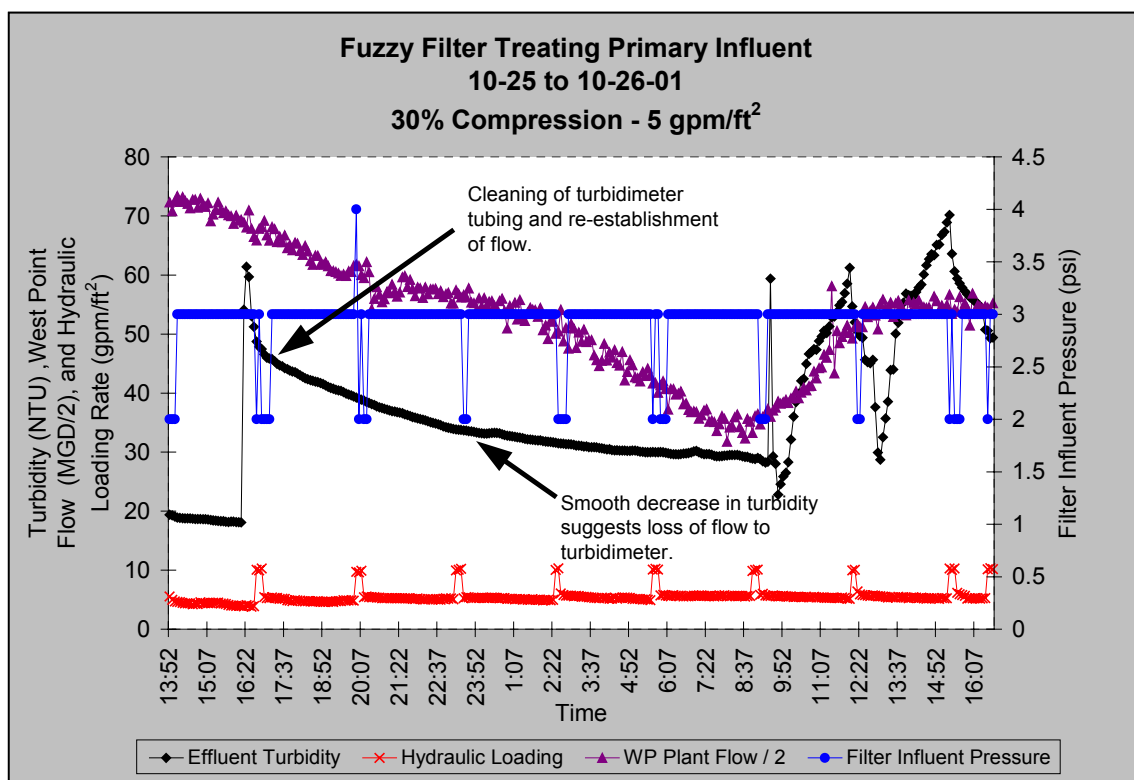


Figure 5. Fuzzy Filter Treating Primary Influent. Typical Performance Trend Showing Questionable Turbidimeter Measurements

As shown in Figure 5, loss of flow to the effluent turbidimeter was characterized by a smooth decrease in effluent turbidity measurement. As feed tubing to the turbidimeter became plugged with solids and flow to the turbidimeter stopped, solids began to settle out in the turbidimeter photo cell. As the solids settled, the measured turbidity gradually decreased.

Steep rises in turbidity in the middle of filter runs normally corresponded with periods of turbidimeter cleaning by operations staff. Based on notes made by operations staff and on the appearance of the graphs generated from the testing, periods of accurate turbidimeter readings were generally limited to initial filter runs for each test condition and a few isolated test conditions after reconfiguration of the turbidimeter. During periods when the turbidimeter was not functioning properly, the actual effluent turbidity was probably higher than the measured turbidity (i.e., the Fuzzy Filter performance was poorer than indicated by the turbidity measurements).

Typical graphs of filter performance during timed backwash (every three hours) and backwash based on pressure are shown in Figure 6 and Figure 7, respectively, for periods when the turbidimeter was thought to be functioning properly during most of the test.

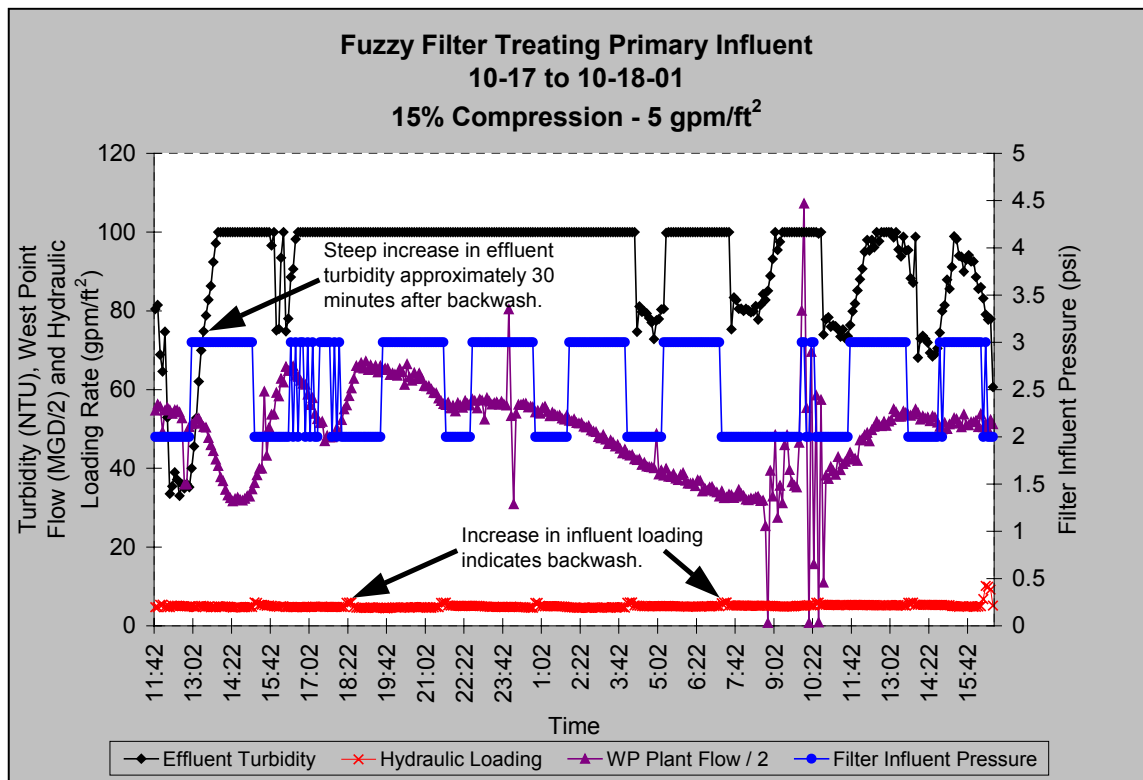


Figure 6. Fuzzy Filter Treating Primary Influent. Performance Trend Showing Good Turbidity Measurements and Timed Backwash Trigger

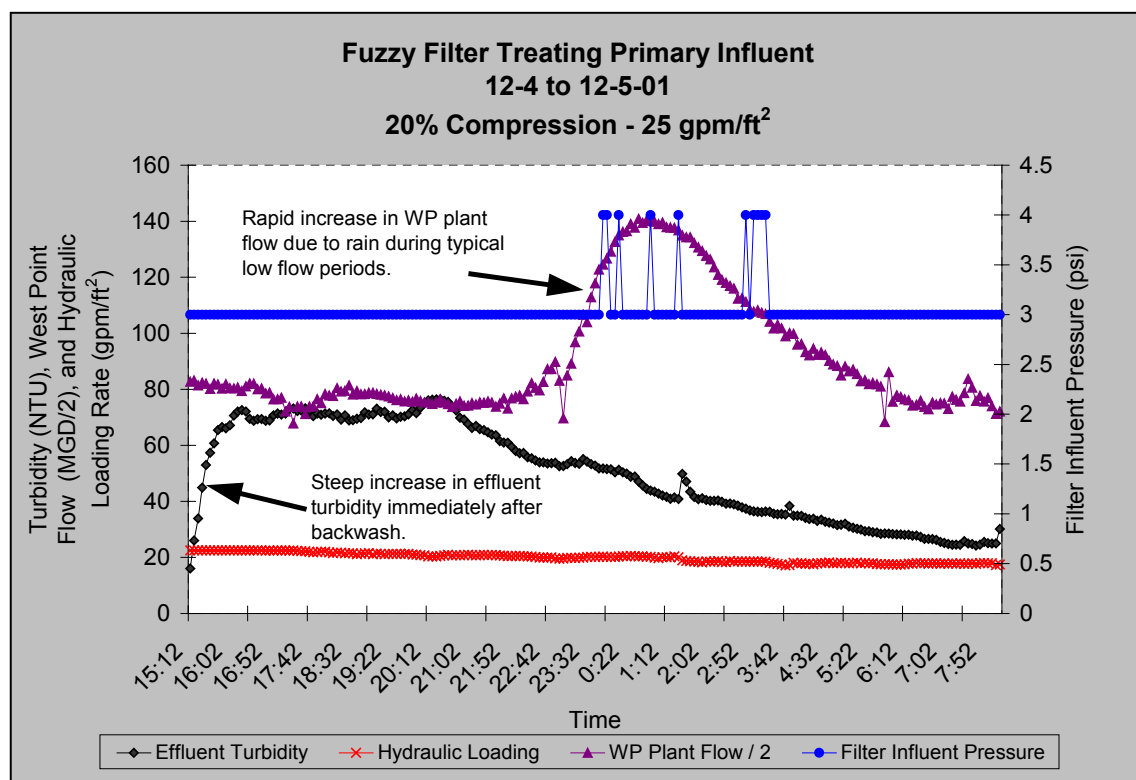


Figure 7. Fuzzy Filter Treating Primary Influent. Performance Trend Showing Good Turbidity Measurements and Pressure Triggered Wash Cycle.

During the trial using timed backwash (see Figure 6), effluent turbidity increased rapidly at the start of the first filter run. Increases in the truncated filter influent pressure occurred at the same time as the increases in effluent turbidity. Similar trends were observed at the beginning of filter runs later in the test. In the middle of the test, the turbidity did not decrease after wash cycles, probably because there was a lack of flow through the turbidimeter or because the photo cell was completely filled with solids. The peak turbidity of 100 NTU recorded corresponds to the upper detection limit of the turbidimeter used during the testing.

During the trial when filter influent pressure was used to trigger a wash cycle, a similar effluent turbidity trend was observed at the start of the first filter run (see Figure 7). A steep increase was observed immediately after the wash cycle. After the steep increase, the effluent turbidity leveled off and then decreased over time. Although loss of flow to the turbidimeter is the likely cause of this decrease in effluent turbidity, the large increase in WP plant flow during nighttime hours due to rainfall may have diluted incoming turbidity to low levels. No increases in filter influent pressure were recorded during the trial run because the PLC values were truncated. As with the timed wash cycle trial run, increases in the filter influent pressure were not sufficient to trigger a wash cycle.

Pressure Buildup

A Schreiber representative was at the site from December 4, 2001, through December 6, 2001, to investigate the performance of the Fuzzy Filter and to troubleshoot problems. Several short duration tests at different conditions were performed with primary influent during that time. Grab samples were taken of the influent and effluent and measured for turbidity at the beginning of a filter run for each test. Influent and effluent turbidity at a hydraulic loading rate of 15 gpm/ft² and filter influent pressure for 0, 20, and 27.5% bed compressions are shown in Figure 8, Figure 9, and Figure 10 respectively.

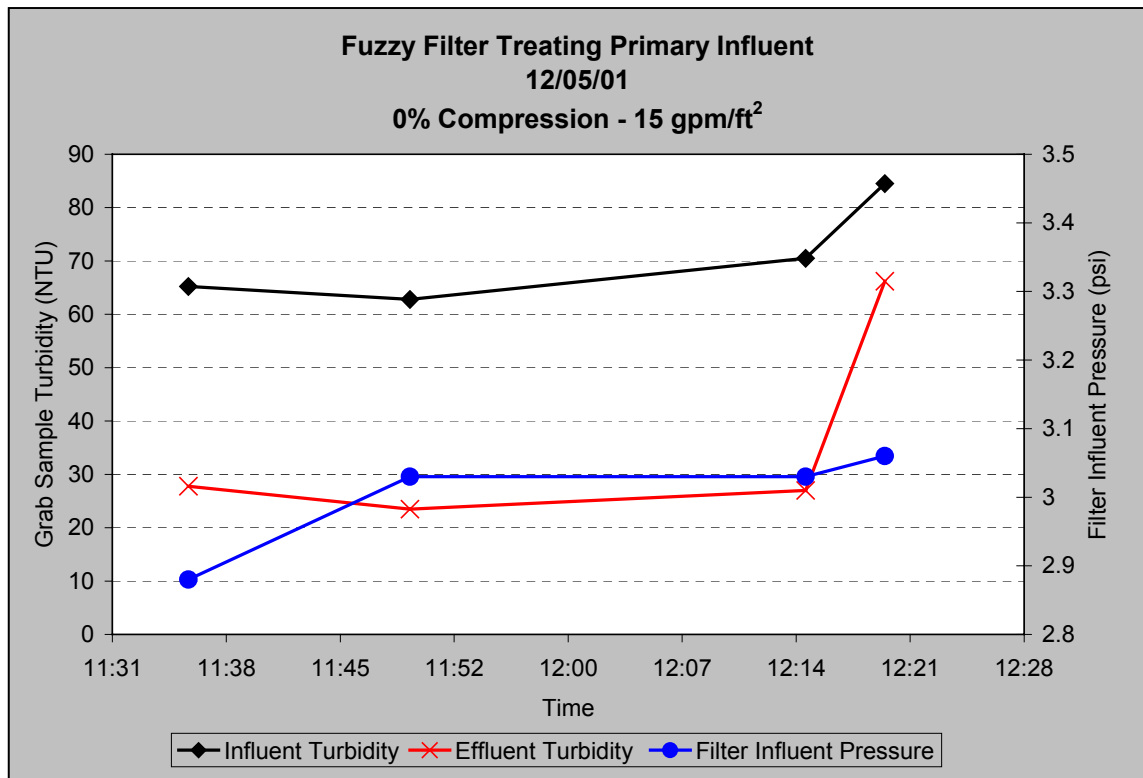


Figure 8. Fuzzy Filter Treating Primary Influent. Turbidity and Filter Influent Pressure Trend at 0% Compression and 15 gpm/ft²

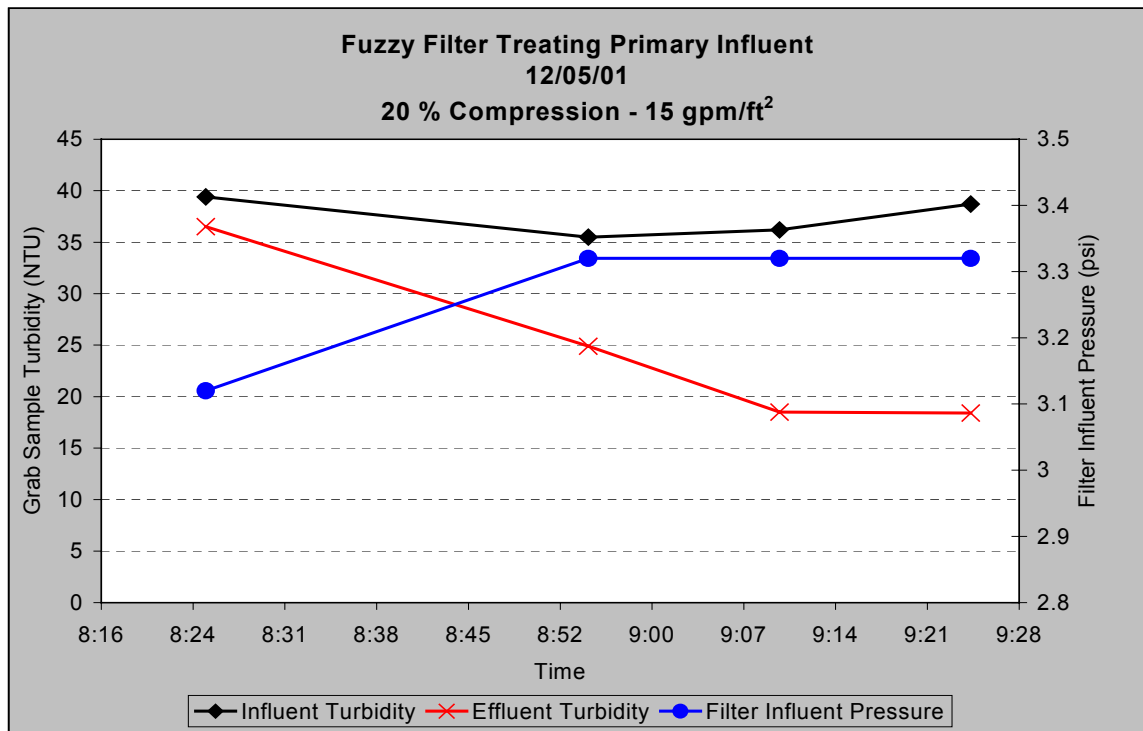


Figure 9. Fuzzy Filter Treating Primary Influent. Turbidity and Filter Influent Pressure Trend at 20% Compression and 15 gpm/ft²

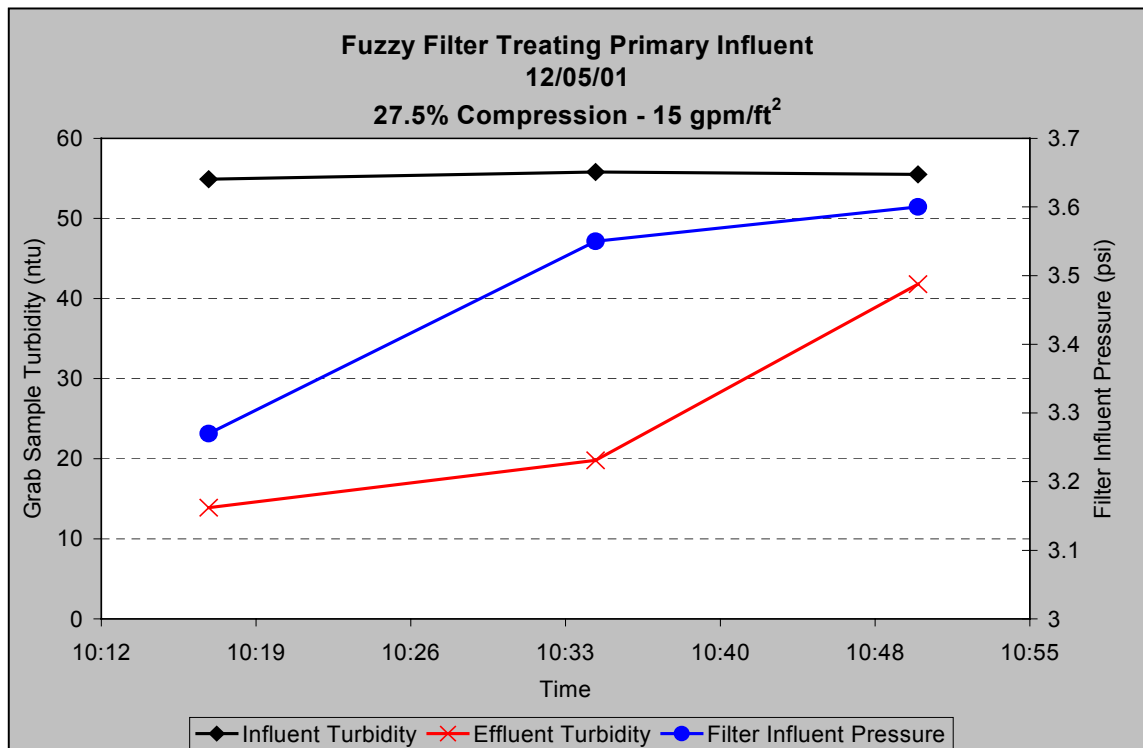


Figure 10. Fuzzy Filter Treating Primary Influent. Turbidity and Filter Influent Pressure Trends at 27.5% Compression and 15 gpm/ft²

An initial rapid increase in filter influent pressure, followed by a period of relatively constant filter influent pressure was observed for all trials (see Figure 8, Figure 9, and Figure 10). During the testing at 0% and 27.5% compression, a rapid increase in effluent turbidity was noted after a short period without a significant increase in filter influent pressure (see Figure 8 and Figure 10). During the 20% compression trial, operations staff visually noted large increases in suspended solids after a similar period of operation, and then stopped the test (Figure 9). Operations staff also noted thick layers of solids at the bottom of the filter bed during each test.

These results suggest that solids rapidly accumulated at the very bottom of the filter bed with a consequent increase in filter influent pressure. The initial blinding of the bottom layer of media did not create a sufficient increase in filter influent pressure to initiate an automatic backwash. Because the pore space available to flow became clogged, flow began to bypass the media bed along the sidewalls. This led to an increase in turbidity, and probably to an increase in suspended solids as well, in the effluent. Since few solids were being removed and stored within the media bed during bypass along the sidewalls, no further increase in filter influent pressure was observed.

Removal Efficiency

The calculated removals of measured parameters across the Fuzzy Filter are shown in Table 16. The laboratory data used to calculate the removals is included in Appendix E.

Table 16. Fuzzy Filter Treating Primary Influent. Calculated Removal Efficiencies.

Date of Test	Hydraulic Loading Rate (gpm/ft ²)	Bed Comp. %	% Removal							
			tCOD	sCOD	TSS	VSS	NH ₄	TKN	PO ₄	t-P
10/24/01	5	30	27.6	NA	29.7	15.1	22.0	NA	NA	NA
10/25/01	5	30	NA	NA	NA	NA	NA	NA	NA	NA
10/28/01	5	10	0.2	(-)	14.8	9.6	NA	NA	NA	NA
10/29/01	10	10	(-)	NA	(-)	(-)	NA	(-)	(-)	2.1
10/30/01	15	12.5	(-)	NA	(-)	(-)	NA	NA	NA	NA
10/31/01	15	12.5	(-)	NA	46.7	16.3	NA	NA	NA	NA
11/5/01	10	20	(-)	NA	17.1	(-)	NA	NA	NA	NA
11/6/01	10	20	(-)	28.1	38.0	12.0	(-)	NA	(-)	NA
11/7/01	15	20	NA	NA	NA	NA	4.8	NA	12.1	(-)
11/8/01	15	20	12.9	3.0	44.3	20.0	26.6	NA	NA	NA
11/12/01	15	20	NA	NA	71.9	69.9	35.7	NA	50.0	NA
11/13/01	10	30	2.4	(-)	71.6	55.9	12.0	18.2	8.0	11.6
11/14/01	15	30	NA	NA	75.8	68.1	NA	NA	26.3	NA
11/15/01	18	30	17.2	(-)	6.3	12.5	NA	NA	NA	NA
11/19/01	20	30	NA	NA	75.1	63.5	NA	NA	NA	NA

Readings of TSS and volatile suspended solids (VSS) removal increased with increasing bed compression, approaching 70 to 75%. However, removals of this magnitude seem improbable, based on visual observations made during the primary testing. The removal of TSS is likely

overstated due to non-representative effluent samples. Removals of other compounds were marginal.

Using the Fuzzy Filter to treat primary influent has not been tested before. Prior tests have focused primarily on secondary effluent filtration. The nature of the primary solids is quite different from that of the secondary solids. In the case of primary influent, the particle size is larger, and solids have a greater tendency to stick or gum due to a higher grease content in the wastewater. More importantly, the solids concentration and the solids loading rate are much higher in a primary application; the solids loading rates are 10 to 15 times higher than in a typical secondary effluent. The combination of larger particles and a much higher solids-loading rate caused the bottom layer of the filter media to rapidly clog.

Based on the limited Fuzzy Filter performance data during primary testing, the project team concluded that performance of the Fuzzy Filter in treatment of primary influent would not improve with chemical addition. A chemical coagulant would further increase solids loading to the filter and the size of the flocculated solids. Therefore, even shorter filter runs and greater solids breakthrough would be expected. As a result, testing of the Fuzzy Filter for primary treatment was stopped on December 5, 2001, and testing with chemical addition was not performed.

Tertiary Treatment With No Chemical Addition

The Fuzzy Filter was tested in a tertiary application in January and February 2002. Chlorinated and screened secondary clarifier effluent from the West Point Wastewater Treatment Plant was used for influent to the Fuzzy Filter. The tertiary testing with no chemical addition included an operational condition testing phase and an extended testing phase. The objective of the first phase of testing was to establish acceptable operating parameters for the filter. Extended testing was used to evaluate the performance of the filter over a longer period of time.

Typical Performance

The Fuzzy Filter was tested under a variety of conditions during the operational condition testing state and under typical variations in influent conditions. Graphs of influent and effluent turbidity, and filter influent pressure for selected test conditions at 10%, 20%, and 30% bed compression are presented in the following sections. The intent of the following sections is to discuss typical performance and to identify factors that influence both the Fuzzy Filter operation and the resulting effluent quality.

10% Compression

Influent and effluent turbidity, filter influent pressure, hydraulic loading to the Fuzzy Filter, and West Point Plant flow for a typical test at 10% compression and a hydraulic loading rate of 32.5 gpm/ft² (130 gpm) are shown in Figure 11.

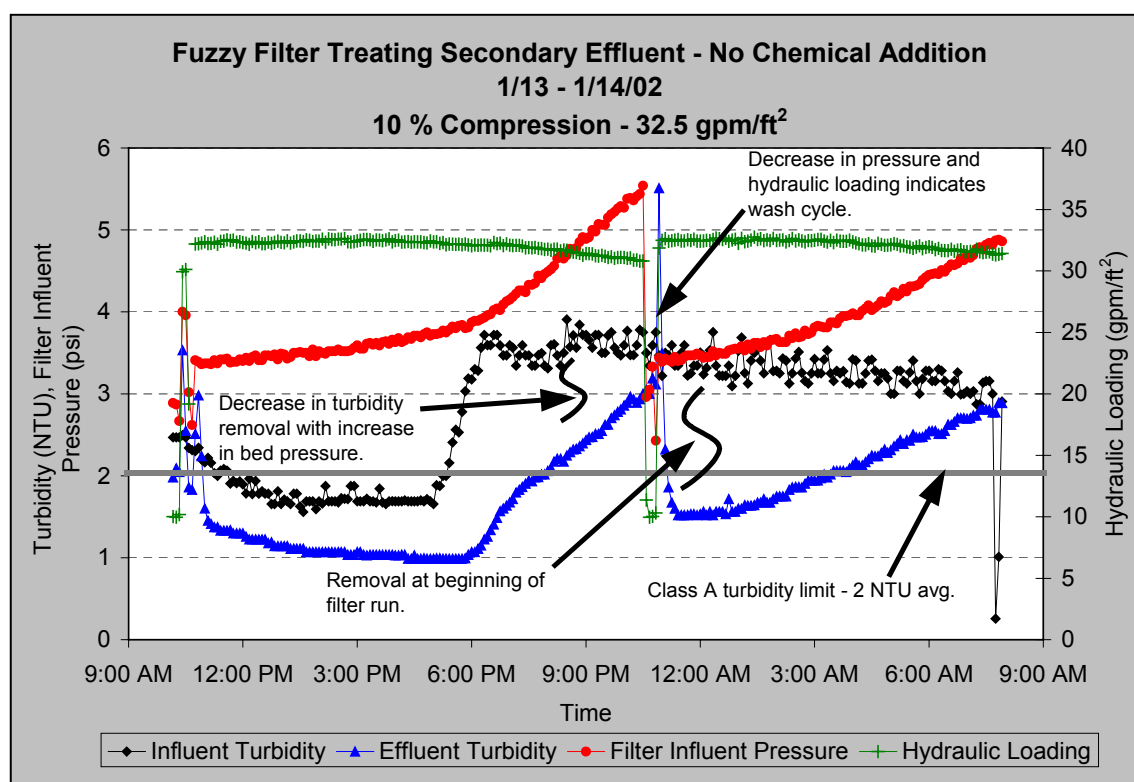


Figure 11. Fuzzy Filter Treating Secondary Effluent - No Chemical Addition. Typical Performance at 10% Compression and 32.5 gpm/ft².

Wash cycles are indicated in the graph by a decrease in hydraulic loading and a decrease in filter influent pressure. As can be seen in Figure 11, filter run time was approximately 12 hours during this test. At the beginning of each filter run, effluent turbidity levels rose higher than influent turbidity levels. After a short period of time, the effluent turbidity levels decreased below influent turbidity levels. Testing was performed during later stages of testing to determine the cause of this spike in effluent turbidity. These tests showed that a buildup of solids in the effluent pipe between the fuzzy filter and the automatic effluent isolation valve was the cause of the spike. As the filter was backwashed, solids were deposited in the short length of pipe upstream of the effluent isolation valve. When the filter was returned to service, the solids were flushed through the pipe and resulted in a short-term increase in turbidity. Because the spike was a consequence of the washing period and was caused by the location of the effluent isolation valve, it is not representative of the performance of the Fuzzy Filter just after the wash cycle period. Data from the sampling used to investigate this phenomenon is included in Appendix D.

During the beginning of the first filter run, influent turbidity was relatively low. Increases in influent turbidity caused an immediate increase in solids loading on the filter. In the first filter run, the increase in influent turbidity caused an increase in the slope of the filter influent pressure curve. Turbidity removal also deteriorated at this time. As more solids were captured

in the media bed, the media head loss accelerated, resulting in progressive increases in the filter influent pressure.

As the filter influent pressure increased with a relatively constant influent turbidity, the percentage removal of turbidity decreased. This decrease in removal efficiency resembles a "breakthrough" and is thought to be due to solids being transported through the bed. As solids are retained on the bed, the effective pore size of the media decreases, increasing the velocity of flow through the pore spaces. Shear forces on the retained particles cause detachment and subsequent movement of the particles deeper into the bed. As particles move farther into the filter bed, the same processes occur, finally resulting in particles exiting the filter bed and increasing effluent turbidity.

During the second filter run (shown on right side of Figure 11), the influent turbidity and the initial percentage removal of turbidity were higher than in the first run. After a short period of low effluent turbidity, turbidity removal efficiency began to decrease. During the second filter run, the test was stopped prior to automatic backwashing to begin another test. However, effluent turbidity was breaking through and approaching the influent value.

During this test condition, the wash cycle was automatically controlled by filter influent pressure. The wash cycle pressure set point was set at approximately 1.75 psi above the clean bed filter influent pressure. Note that the turbidity excursions could have been prevented if the wash pressure set point had been decreased to balance the pressure and turbidity breakthrough point. A reduction in the pressure setting also would have decreased the filter run time. In order to optimize operation and performance, the operator must select the backwash trigger point for the Fuzzy Filter to balance the requirement for an extended filter run with the target effluent quality.

20% Compression

Typical Fuzzy Filter performance at 20% compression and 30 gpm/ft² (120 gpm), including influent and effluent turbidity, hydraulic loading, and filter influent pressure, is shown in Figure 12.

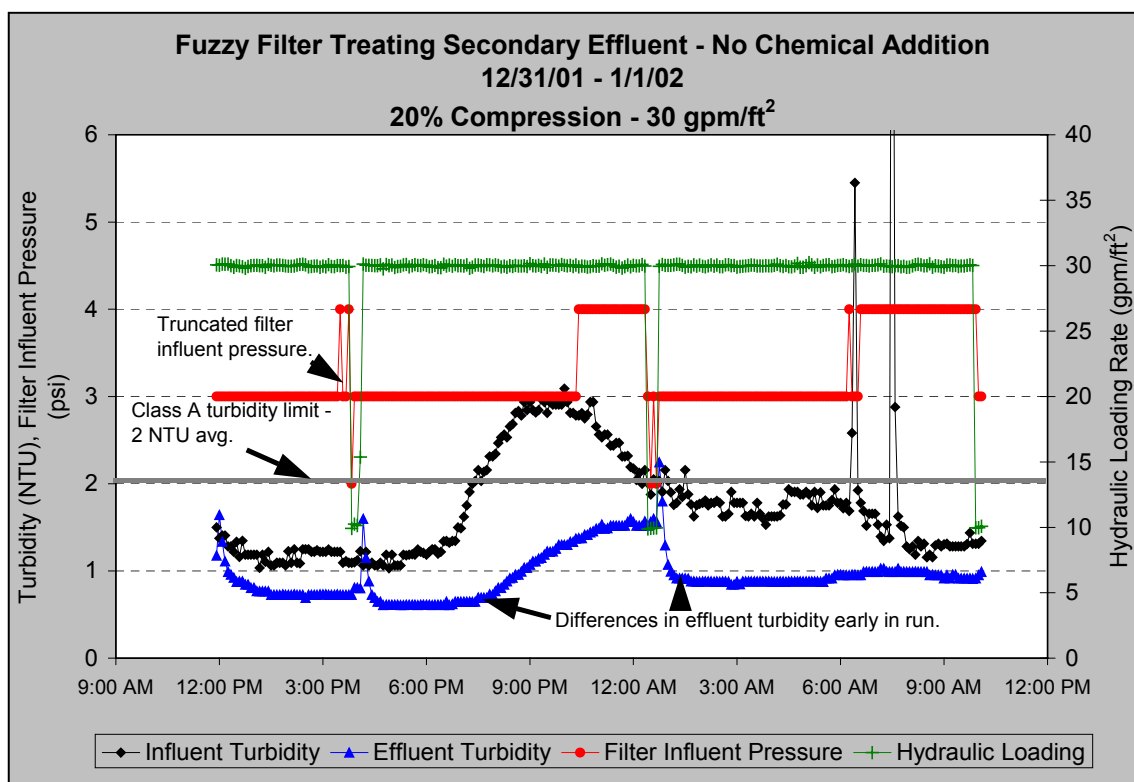


Figure 12. Fuzzy Filter Treating Secondary Effluent - No Chemical Addition. Typical Performance at 20% Bed Compression and 30 gpm/ft².

In Figure 12, the filter influent pressures recorded in the PLC were truncated to integer values. This truncation is typical for all runs prior to January 2, 2002. With truncated values, the resolution of pressure measurements is too coarse, making it difficult to discern increases in filter influent pressure or the magnitude of increases due to differences in operational conditions.

Like the observations at 10% compression, there was an initial spike in effluent turbidity followed by a period of relatively stable effluent turbidity (see previous section for discussion of spiking phenomenon). During the first filter run at 20% compression, the influent turbidity was approximately 1.2 NTU. During the second run at 20% compression, the influent turbidity was approximately 1.9 NTU. The resulting effluent turbidity was also different; effluent turbidity was approximately 0.5 NTU during the initial part of the first run and 0.9 NTU during the second run, reflecting the increase in influent turbidity. Later in the filter run, as more solids were retained within the media, the turbidity removal efficiency decreased.

Considering differences between the Fuzzy Filter's performance at 10% and 20% compression, effluent turbidity at the beginning of the run was slightly lower at 20% compression than at 10% at similar influent turbidities. As the media bed compression is increased, the effective pore size decreases. Therefore, at 20% compression, the effective pore size is smaller and

greater removal at the beginning of the filter run is expected. However, an increase in effluent turbidity can not be avoided once the influent turbidity is increased.

In the 20% compression test, the increase in effluent turbidity never exceeded 2 NTU. Relative to the performance of the filter in the 10% case, this is likely due to lower influent turbidities during most of the 20% compression test than in the 10% compression test. Even if complete breakthrough had occurred, the effluent turbidity would not have exceeded the effluent limit in the 20% compression test.

30% Compression

A typical performance graph for 30% compression and a 40 gpm/ft² hydraulic loading rate (160 gpm) is shown in Figure 13 and includes hydraulic loading, influent and effluent turbidity, and filter influent pressure.

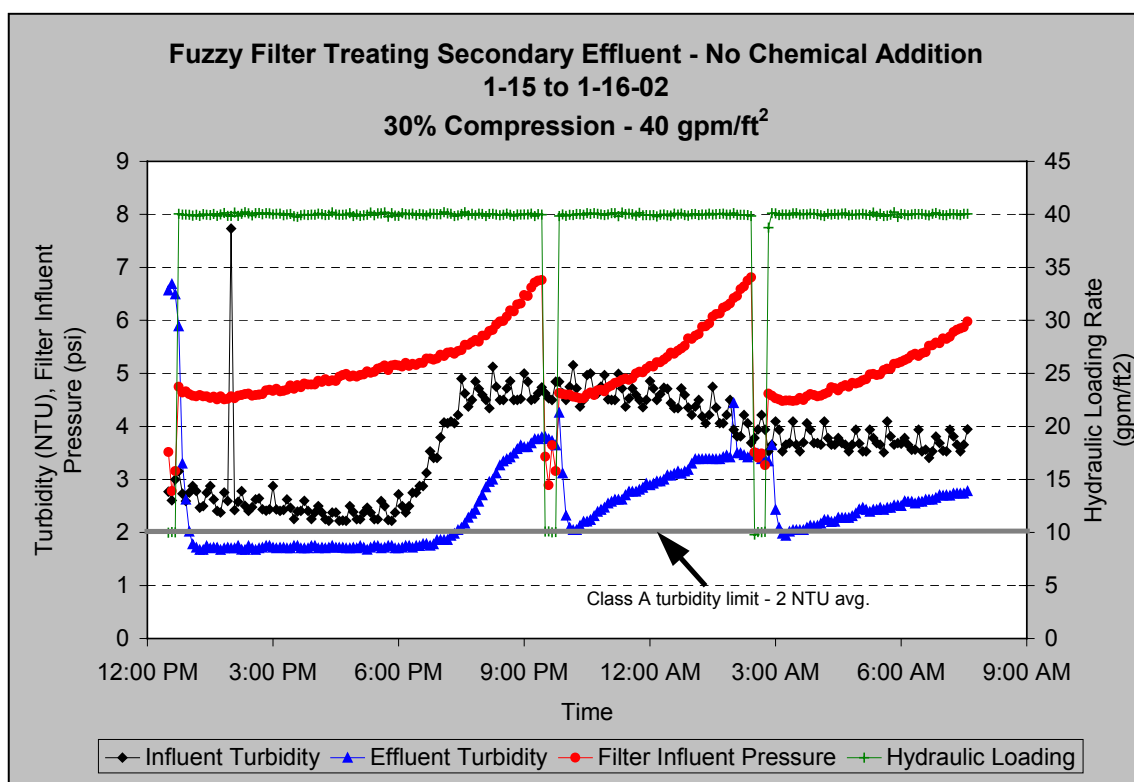


Figure 13. Fuzzy Filter Treating Secondary Effluent - No Chemical Addition. Typical Performance at 30% Compression and 40 gpm/ft².

There are several differences in Fuzzy Filter performance under 30% compression relative to the 10% and 20% compression cases that warrant further discussion. First, the filter run times during the 30% compression case were much shorter than in the 10% and 20% cases. This is likely the result of the smaller storage volume within the bed, the higher solids loading rates on the filter, and the resulting higher rates of media bed headloss.

During the first filter run in the 30% case, influent turbidity was between 2 NTU and 3 NTU, and effluent turbidity was slightly lower than 2 NTU. During the second filter run at 10% compression (Figure 11), similar effluent turbidities were achieved during higher influent turbidities relative to the 30% compression case. The higher removal efficiency at 10% compression could be due to two factors: pore velocity through the media bed, and differences in the nature of the solids in the influent to the Fuzzy Filter. The velocity in the pore space was higher in the 30% compression case, because the compression was higher and because flow to the Fuzzy Filter was higher (160 gpm vs. 130 gpm when the compression was 10%). Higher velocities have the potential to cause more of the particles to be washed through the bed.

Differences in the characteristics of the influent could have also contributed to the observed differences in removal. Previous studies on the performance of the Fuzzy Filter have concluded that the principal removal mechanisms are interception and straining (Caliskaner, *et al* 1999). Under these mechanisms, the size and numbers of particles in the influent would affect observed removals. Higher concentrations of particles in the 10% compression case would have increased the potential for capture. Additionally, if particles were smaller in the 30% compression case, relative to the 10% case, lower removal efficiencies could have resulted, despite the smaller pore size at the higher bed compressions.

Although the Fuzzy Filter had a smaller pore size (and therefore a greater potential for removal of influent particles) at 30% compression, this advantage was probably offset in the other cases by differences in pore velocity and the characteristics of the influent. While the magnitude of each factor was not quantified in the pilot testing, differences in performance do illustrate the importance of both influent flow and influent characteristics on removals in the Fuzzy Filter. The differences also suggest that higher compressions may not always be beneficial relative to Fuzzy Filter performance.

Filter Performance Under Special Conditions

Under normal conditions, influent to the Fuzzy Filter during tertiary testing consisted of screened and chlorinated secondary effluent from the West Point WWTP. However, during periods of high flow to the West Point plant, flow in excess of 300 MGD received primary treatment and then was bypassed around the secondary treatment system. Therefore, influent to the Fuzzy Filter was a blend of true secondary effluent and primary effluent during these periods. The percentages of each depended on the flow rate coming into the plant.

Figure 14 shows filter performance under increased flow conditions to the West Point WWTP and includes influent and effluent turbidity, filter influent pressure, and West Point flow.

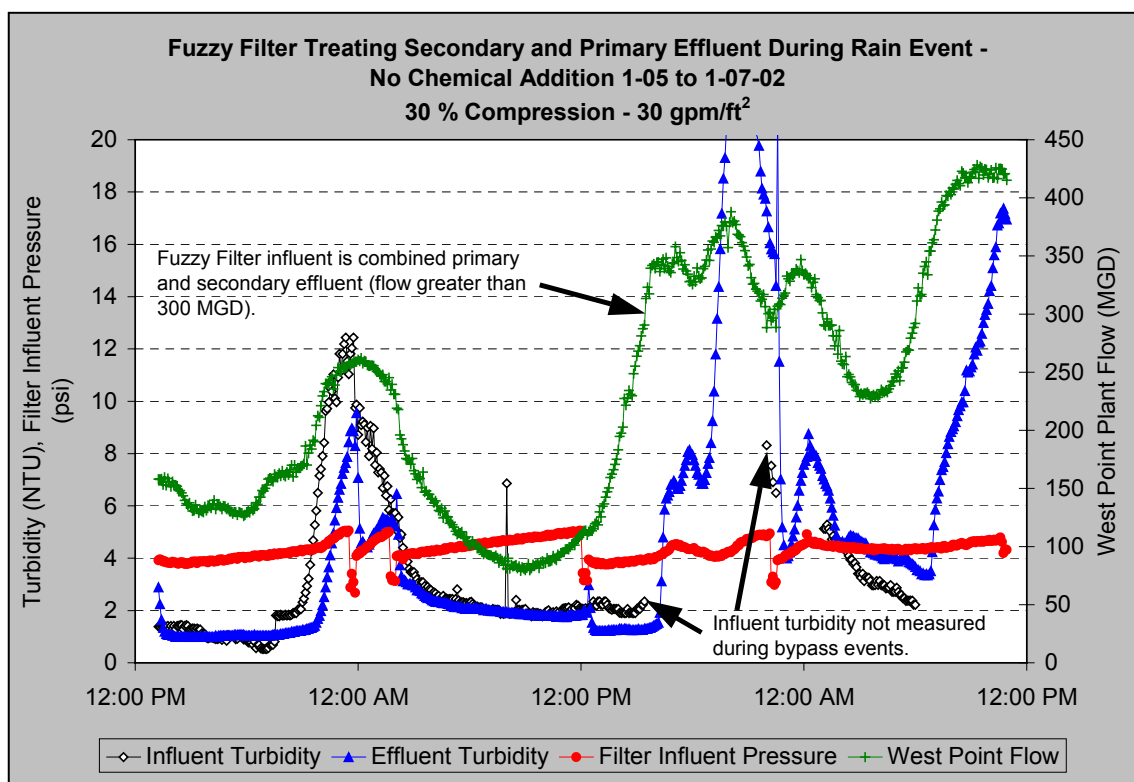


Figure 14. Fuzzy Filter Treating Secondary Effluent - No Chemical Addition -Typical Performance Treating Both Primary and Secondary Effluent during West Point Bypass Events at 30% Compression and 30 gpm/ft².

The Fuzzy Filter performance shown in Figure 14 is over a two-day period during part of which the Fuzzy Filter received combined secondary and primary effluent. During the first day of operation, flow to the West Point plant was elevated, due to a rain event, but did not reach 300 MGD. Influent turbidity to the Fuzzy Filter increased significantly during this increase in flow. The increase was due to the increased flow to the West Point plant and subsequent decreased removal of particulates in the secondary clarifiers. The rapid increase in influent turbidity had a detrimental effect on the performance of the Fuzzy Filter. While some removal was still achieved, effluent turbidity rose rapidly to values of almost 10 NTU.

The effect of increased WP plant flow on the particle sizes of the secondary effluent is not known. However, the increased flows likely would have resulted in an increase in overall particle quantity and a wider distribution of particle sizes due to the decreased removal efficiency in the secondary treatment process. The increase in turbidity loading, along with a likely increase in particle size, resulted in a rapid increase in effluent turbidity through the filter. It also caused an increase in the rate of filter influent pressure buildup, resulting from a greater rate of solids accumulation in the filter. The filter was washed during the first period of increased influent turbidity, as indicated by the drop in filter influent pressure. However, effluent turbidity immediately after the wash cycle did not return to the levels observed at the beginning of the test. Additionally, after influent turbidity decreased to more typical levels,

effluent turbidity also decreased, but removal efficiency was lower than observed in the other cases considered in this section. This illustrates the dependence of Fuzzy Filter performance on the incoming flow characteristics.

During the second day of the test, West Point plant flow exceeded the secondary treatment capacity of 300 mgd, causing the primary treated flow to bypass around the aeration basins and secondary clarifiers. The turbidity of the combined effluent was not measured at the West Point plant. The location of combination is downstream of the turbidity monitoring location. Therefore, influent turbidities to the Fuzzy Filter are not shown. The bypass of the primary effluent and its combination with secondary treated flow under increased flow conditions was accompanied by a rapid increase in Fuzzy Filter effluent turbidity and a corresponding increase in filter influent pressure. After the initial increase, the media headloss actually decreased and effluent turbidity increased again to very high levels.

The decrease in filter influent pressure that occurred at the same time as an increase in effluent turbidity suggests that the media bed was bypassed and a breakthrough of solids occurred during this period. In the testing of the Fuzzy Filter with primary influent, the Fuzzy Filter was quickly blinded with primary solids, suggesting that larger solids associated with bypassed primary effluent likely contributed to filter blinding. The high effluent turbidity level during this period is attributed to the change in the nature of the particles (from pure secondary to a mix of secondary and primary effluent particles) and an increase in solids entering the filter. As seen in the previous filter run, increases in the plant flow increased the resulting turbidity of the influent to the Fuzzy Filter.

During the high flow excursions at the West Point plant when the turbidity and the nature of the particles in the feed changed, the performance of the Fuzzy Filter deteriorated very quickly. The degradation of effluent quality under these conditions shows that Fuzzy Filter performance is dependent on influent conditions. It also shows that rapid changes in influent quality are detrimental to the performance of the filter. In order to achieve stable effluent quality, influent conditions to the filter must be stable without significant fluctuations in turbidity or in the nature of the particles.

Parameters Affecting Fuzzy Filter Performance

The two key operational parameters that are indicative of the Fuzzy Filter performance are effluent turbidity and filter run time between wash cycles. To be suitable for treatment of secondary effluent without chemical addition, the Fuzzy Filter must be able to maintain effluent quality below limits desired for Washington State Class A reclaimed water. In addition, to be practical, the run times for the Fuzzy Filter must be of sufficient duration to keep the number of filters required and wash cycle waste volume reasonable. An effective installation will balance these two parameters.

Based on the discussion presented in the previous section, other studies of Fuzzy Filter performance, and general filtration theory, many factors can affect the Fuzzy Filter performance:

- **Influent Flow Rate:** The contribution of increases in flow to the reduction of Fuzzy Filter performance were not quantifiable from the data in previous sections. However, increased flow does have the potential to affect effluent quality and run time. Higher flow rates cause higher solids loading, and that results in shorter filter run times due to the increased rate of solids accumulation within the media bed. Higher pore velocities result in increased shear forces on particles retained within the bed, and the potential for detachment of particles is increased, but the contribution of detachment to the reduction of effluent quality was not quantified in this study.
- **Influent Turbidity Concentration:** Based on the typical performance graphs presented earlier, increases in influent turbidity normally increased effluent turbidity. Higher influent turbidities corresponded to higher removal efficiencies during the initial periods of the filter run, but generally the effluent turbidity was higher than for lower influent turbidity cases. Rapid changes in the influent turbidity concentration also had a detrimental effect on Fuzzy Filter performance as illustrated in the performance graph presented for performance of the Fuzzy Filter under special conditions.
- **Bed Compression:** An increase in bed compression under normal operation (i.e., without excessive flow to the West Point plant) corresponded to lower effluent turbidities during the initial period of the filter run. As the bed compression of the Fuzzy Filter increases, the pore size within the media bed decreases. Small pore size increases the potential for capture of smaller particles. However, smaller pore spaces and higher pore velocity also increase media headloss, increase the potential for detachment and higher effluent turbidity, and provide less available storage volume for solids.
- **Size and Nature of Particles:** Because the Fuzzy Filter particle removal mechanisms are primarily straining and interception, the influent particle size can affect the overall Fuzzy Filter performance. Because the influent particle size was not measured during the study, the effect of this parameter on the Fuzzy Filter performance cannot be addressed in this report.
- **Wash Cycle Pressure Set Point:** A reduction of the wash cycle pressure set point can prevent effluent turbidity breakthrough. However, decreases in wash cycle pressure set point will decrease the run time between wash cycles.

Performance During Operational Condition Testing

Twenty-two separate tests were performed under different operational conditions to evaluate Fuzzy Filter performance in treatment of secondary effluent with no chemical addition. In addition, two extended period tests were conducted. Performance of the filter under extended conditions will be discussed in the Extended Testing Performance subsection. Each of the 22

tests involved operation of the Fuzzy Filter at a set hydraulic loading rate and compression setting. During each test, several parameters were calculated and recorded based on the real-time data recorded by the PLC. Averages of performance and operational parameters were also determined for each separate filter run (filter period between wash cycles) within the test period. The filter-run data set is included in Appendix C. The initial data was filtered to exclude data from filter runs that did not reach the wash cycle due at the end of the test period. Data from filter runs during which secondary bypass events (flows greater than 300 MGD) occurred was also deleted. Influent turbidities recorded by the plant PLC were not representative of Fuzzy Filter influent during these periods.

The following sections present the results of the operational conditions testing in terms of the following:

- Influent turbidity loading impacts on effluent turbidity.
- Filter run time.
- Removal efficiency of pollutants.

Influent Turbidity Loading Impacts on Effluent Turbidity

To provide a basis of comparison that takes into account both influent turbidity and flow, influent turbidity loading was used. The influent turbidity loading is a surrogate parameter and is analogous to the influent solids loading, but uses turbidity as a measure of the influent load. The influent turbidity load is calculated by multiplying the hydraulic loading rate and turbidity, and has units of “gpm/ft²-NTU.” This parameter was calculated from real time data from each filter run and was then averaged over the filter run period for the analysis.

The relationship between influent turbidity loading and effluent turbidity for filter runs between wash cycles is shown in Figure 15.

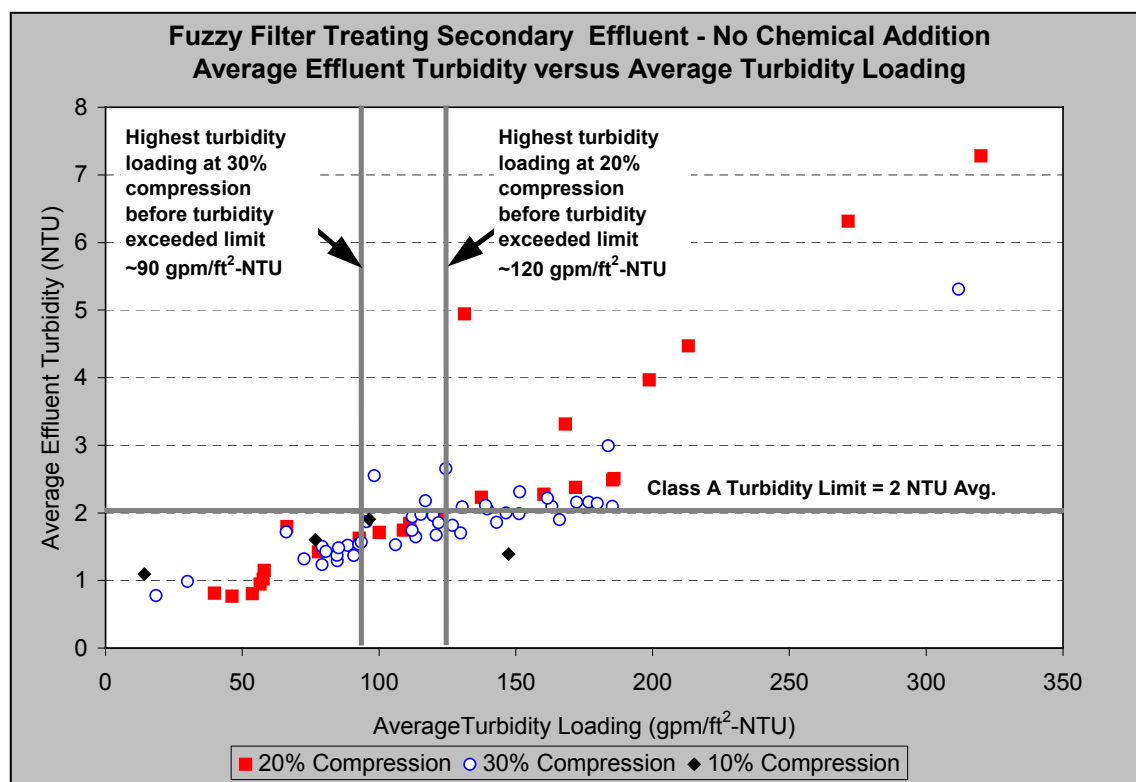


Figure 15. Fuzzy Filter Treating Secondary Effluent - No Chemical Addition. Average Effluent Turbidity Versus Turbidity Loading for Individual Filter Runs

Average effluent turbidity generally increased as the turbidity loading to the Fuzzy Filter increased. Average effluent turbidities at similar turbidity loadings tended to be less for the 30% compression cases than in the 20% compression cases. However, when considering all factors, at 30% compression the maximum turbidity loading, which achieved an average effluent turbidity of 2 NTU was actually lower than in the 20% case. Maximum loadings were approximately 90 gpm/ft²-NTU for 30% compression runs compared to 120 gpm/ft²-NTU for the 20% compression runs. No maximum turbidity loadings were determined for the 10% compression cases due to the limited data available. Without the three filter runs that resulted in average effluent turbidities higher than 2 NTU, the maximum influent turbidity loading to achieve an average effluent turbidity of 2 NTU would increase to values comparable to those of the 20% compression runs.

The average effluent turbidity as a function of average influent turbidity for individual filter runs during operational condition testing is shown in Figure 16.

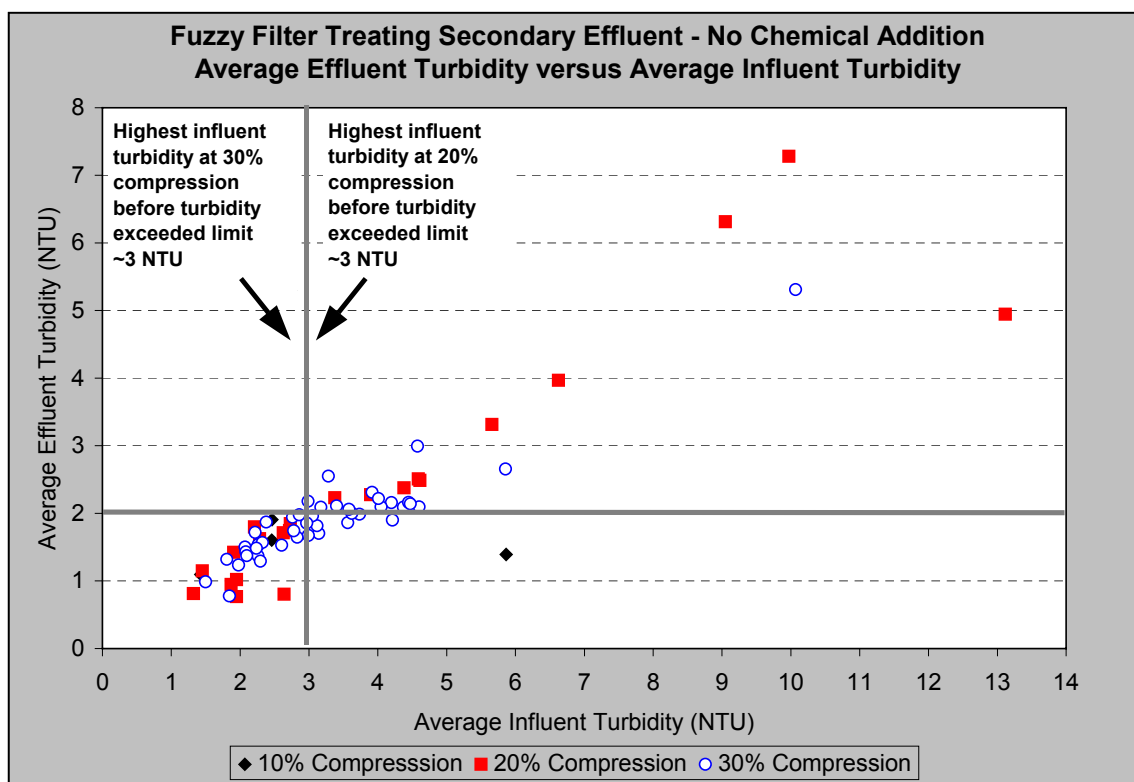


Figure 16. Fuzzy Filter Treating Secondary Effluent - No Chemical Addition. Average Effluent Turbidity Versus. Influent Turbidity for Individual Filter Runs

The effluent turbidity achieved during tertiary treatment with no chemical addition was dependent on the influent turbidity. Under increased influent turbidity conditions, the resulting effluent turbidity was higher. When all data was considered for the 20% and 30% compression cases, an average effluent turbidity of less than 2 NTU was achieved when the average influent turbidity was less than 3 NTU. No maximum influent turbidity was estimated for the 10% compression case due to the limited data available.

The individual filter run data for tertiary treatment with no chemical addition were further separated into different hydraulic loading rate cases for 20% and 30% compression. The average effluent turbidity as a function of influent turbidity loading for 20% and 30% compression at different flow rates is shown in Figure 17 and Figure 18, respectively.

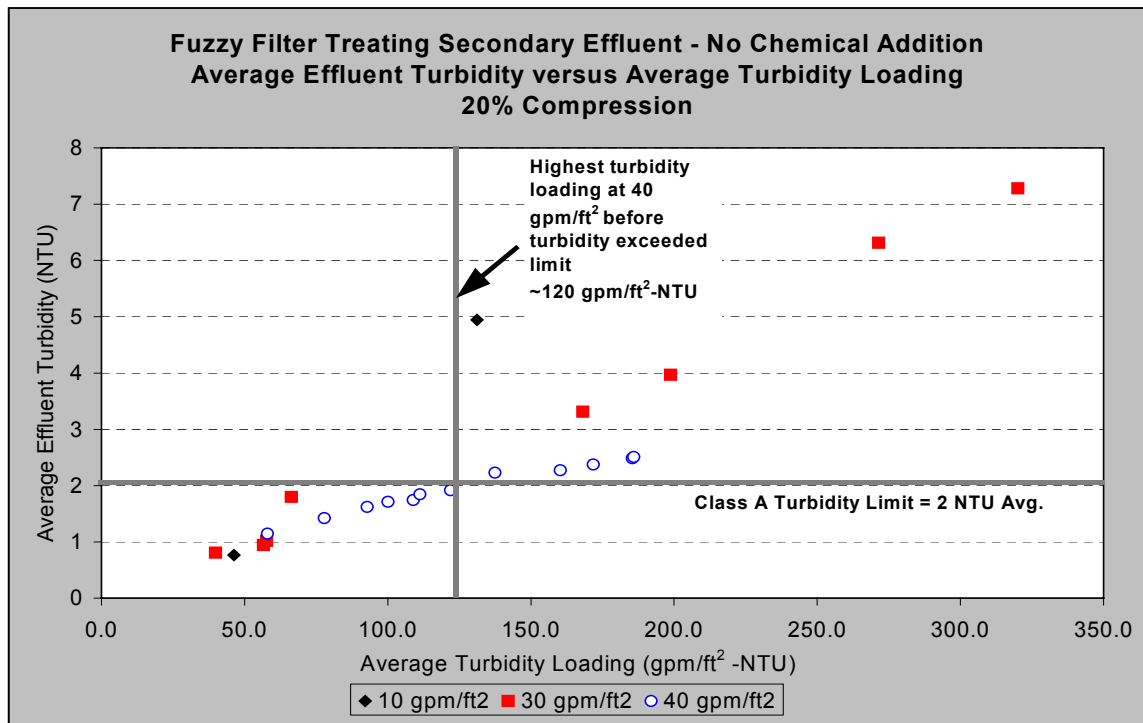


Figure 17. Fuzzy Filter Treating Secondary Effluent - No Chemical Addition. Effluent Turbidity Versus. Turbidity Loading at 20% Compression for Individual Filter Runs.

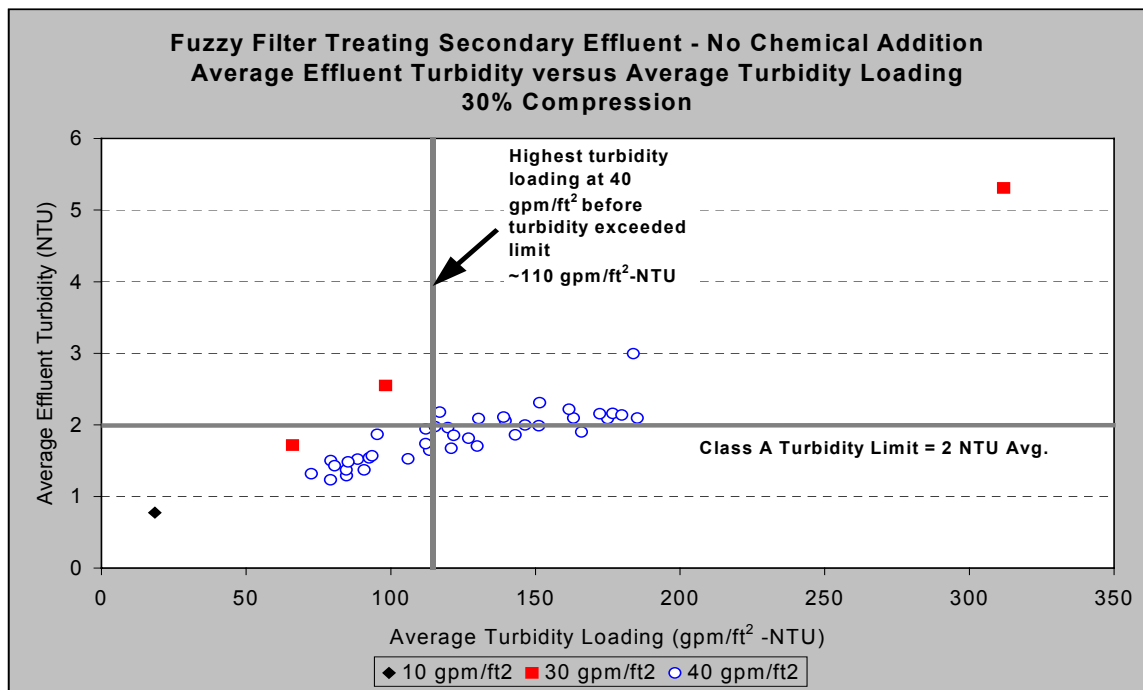


Figure 18. Fuzzy Filter Treating Secondary Effluent - No Chemical Addition. Average Effluent Turbidity Versus Turbidity Loading at 30% Compression for Individual Filter Runs.

The general trend in both graphs suggests that, as the influent turbidity loading increases, the expected average effluent turbidity increases. No maximum turbidity loadings were defined for the 30 gpm/ft² case at either compression because of the limited number of data points available. However, average effluent turbidities for the 30 gpm/ft² hydraulic loading rate tended to be higher than for the 40 gpm/ft² case at equivalent turbidity loadings. Therefore, the maximum permissible turbidity loading would be less than in the 40 gpm/ft² case.

Equivalent turbidity loading rates correspond to higher influent turbidities for the 30 gpm/ft² case relative to loading at 40 gpm/ft². This suggests that the impact of influent flow rate on effluent turbidity is less than the influence of influent turbidity. That is, the increase in effective pore velocity at higher hydraulic loading rates is not as critical to effluent turbidity as added influent turbidity.

For the 40 gpm/ft² loading rate case, the maximum turbidity loading before the turbidity limit was exceeded was slightly higher in the 20% compression case than in the 30% case. No distinct improvement in effluent turbidity at equivalent loading rates was achieved when the compression was increased from 20 to 30%.

Filter Run Time

Another important aspect of filter operation and performance is the filter run time. The filter run time is important from the standpoint of the amount of water that is wasted from the filter and the feasibility for full-scale implementation. The Fuzzy Filter was washed for approximately 20 minutes at a 10 gpm/ft² (40 gpm) flow rate throughout the testing period. Therefore, the percent of water wasted depended primarily on the filter run time and the hydraulic loading rate to the filter. The performance goal was to achieve filter run times of greater than 24 hours and a wash water waste percentage of less than 8%. These parameters are typical of conventional filtration processes. The relationship between filter run time, influent hydraulic loading rate, and percentage of water wasted in operation of the Fuzzy Filter is shown in Figure 19.

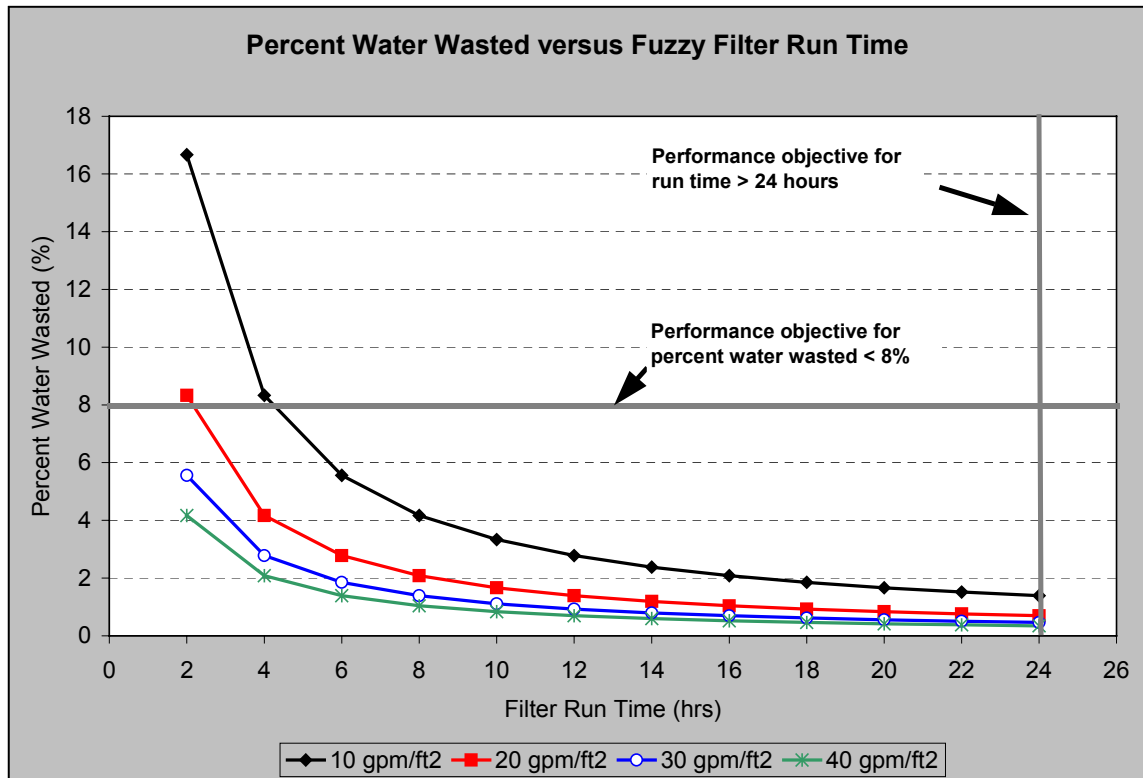


Figure 19. Percent Water Wasted Versus Run Time for Fuzzy Filter With Wash Cycle Duration of 20 minutes.

As shown in Figure 19, only very short run times can be tolerated while still meeting the 8% waste objective. A run time as low as 4 hours at a hydraulic loading rate of 10 gpm/ft² can meet the 8% wash water performance objectives. Lower run times are acceptable at higher hydraulic loading rates. The run times required to meet the 8% waste objective are considerably less than the pilot objective of 24-hour filter runs. Therefore, the 24-hour run time objective was deemed overly aggressive.

The measured run times of the Fuzzy Filter under 20% and 30% compression as a function of influent turbidity loading are shown in Figure 20 and Figure 21, respectively.

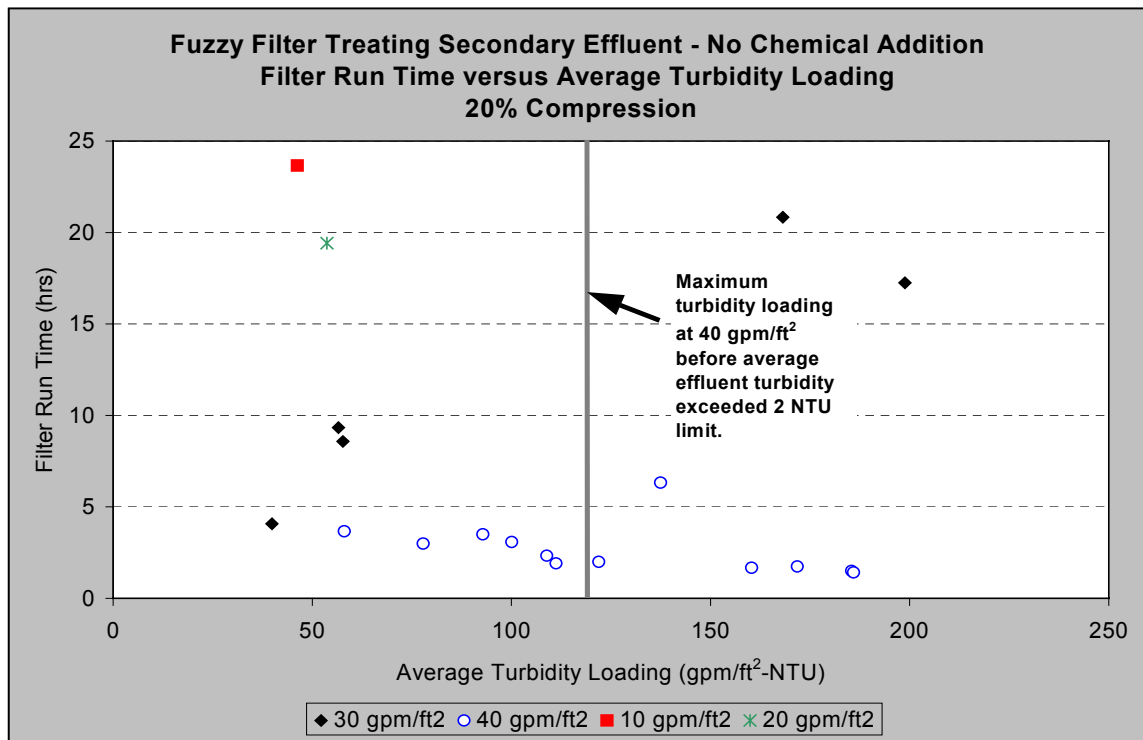


Figure 20. Fuzzy Filter Treating Secondary Effluent - No Chemical Addition. Run Time Versus Turbidity Loading at 20% Compression.

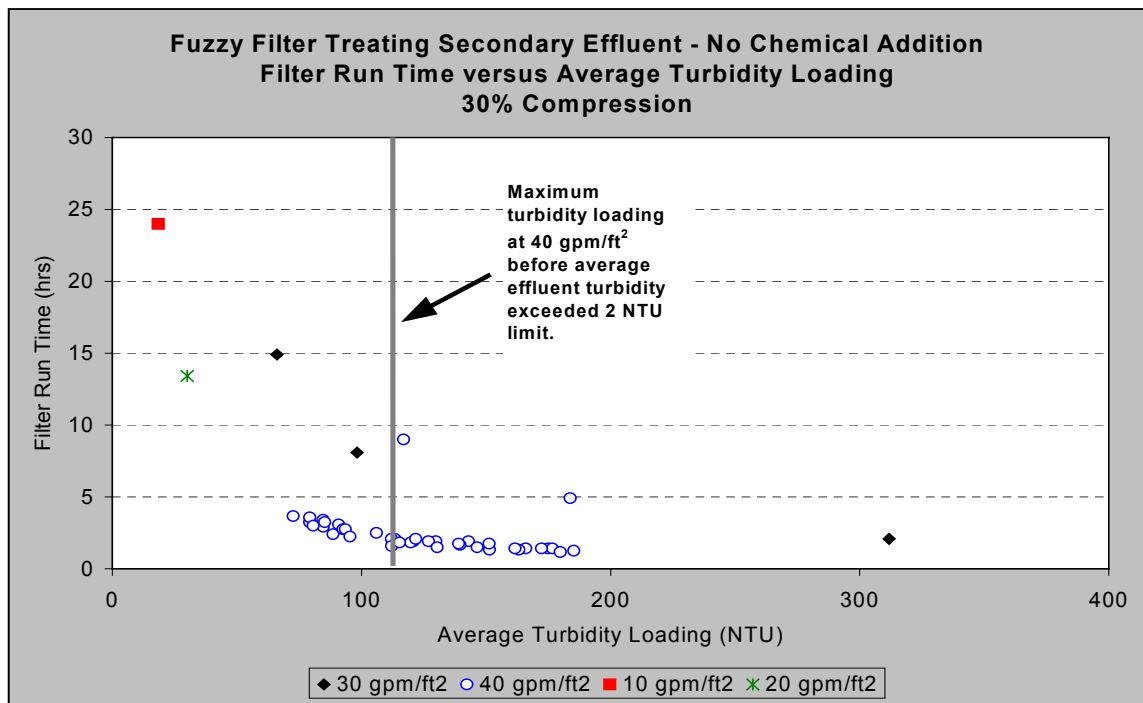


Figure 21. Fuzzy Filter Treating Secondary Effluent - No Chemical Addition. Filter Run Time Versus Turbidity Loading at 30% Compression.

When operated at 20% compression, with the exception of two outlying points (all from the same test), filter run times at 30 gpm/ft² loading rates were below 10 hours. At 40 gpm/ft², filter run times were generally below 5 hours. At 30% compression, the filter run time exceeded 8 hours at a hydraulic loading rate of 30 gpm/ft² except at very high loadings. At 40 gpm/ft², filter runs were between 2 to 4 hours in duration even at lower influent turbidity loading rates, which is considered marginal for practical application.

Except at very low hydraulic loading rates, a 24-hour filter run duration is not feasible based on the test results presented in this report. However, despite not meeting the 24-hour filter run test objective, backwash quantities are acceptable. Even at higher loading rates, particularly 30 gpm/ft², run times are of sufficient length to be feasible in full-scale operation while meeting the 8% backwash volume criteria.

Removal of Pollutants With No Chemical Addition

Laboratory data available from test conditions during operation of the Fuzzy Filter treating secondary effluent with no chemical addition is shown in Table 17, arranged in ascending order by percent bed compression and hydraulic loading rate.

Table 17. Pollutant Removal in Fuzzy Filter Treating Secondary Effluent With No Chemicals

% Compression	Loading Rate (gpm)	Test Condition #	% Removal									
			tBOD	sBOD	tCOD	sCOD	TSS	VSS	TKN	t-P	PO ₄	Turbidity
10	40	12	NA	29	29	NA	NA	NA	NA	19	15	NA
10	100	41	31	NA	3	NA	50	50	NA	13	7	60
10	120	11	NA	0	4	NA	60	40	NA	13	3	NA
10	130	14	NA	(-)	(-)	NA	0	33	NA	13	13	56
10	160	15	NA	NA	17	NA	67	75	NA	11	8	57
20	40	4	NA	NA	(-)	NA	67	100	NA	6	NA	NA
20	40	28	60	NA	20	NA	58	54	NA	12	2	52
20	120	6	NA	NA	NA	NA	19	14	NA	(-)	(-)	NA
20	120	19	17	(-)	(-)	(-)	75	83	(-)	16	20	64
20	120	29	NA	NA	2	NA	45	56	NA	2	(-)	12
20	120	44	0	NA	5	NA	71	71	NA	16	5	NA
20	160	17	45	NA	0	14	54	82	10	13	0	54
30	40	8	NA	NA	NA	NA	86	100	NA	16	13	NA
30	80	7	NA	NA	NA	NA	38	57	NA	NA	NA	0
30	120	10	NA	(-)	(-)	NA	28	33	NA	0	(-)	NA
30	120	13	NA	NA	16	NA	64	88	NA	NA	NA	NA
30	160	16	NA	NA	15	NA	NA	NA	NA	6	4	NA

Notes:

Shaded rows represent extended run periods.

Data shown only for runs during which samples taken for analysis.

The table includes all tests conducted in a tertiary application with no chemical addition. No trends are apparent from the data. The particulate fraction of most pollutants was removed to some degree. Surprisingly, some soluble components were also removed (phosphate - PO₄), possibly associated with removal of colloidal material. The calculated soluble component removal could also be due differences in composite samples or analytical error, since PO₄

levels are low in the influent and effluent (reference Appendix E for influent and effluent values). TSS and VSS removals were high and appear to be independent of influent loading rates and the percent of bed compression on the filter.

Further analysis was conducted on the TSS removal data for the Fuzzy Filter. Real-time PLC values for influent and effluent turbidity were averaged over the testing conditions during which composite TSS samples were taken. Composite TSS as a function of average turbidity is shown in Figure 22.

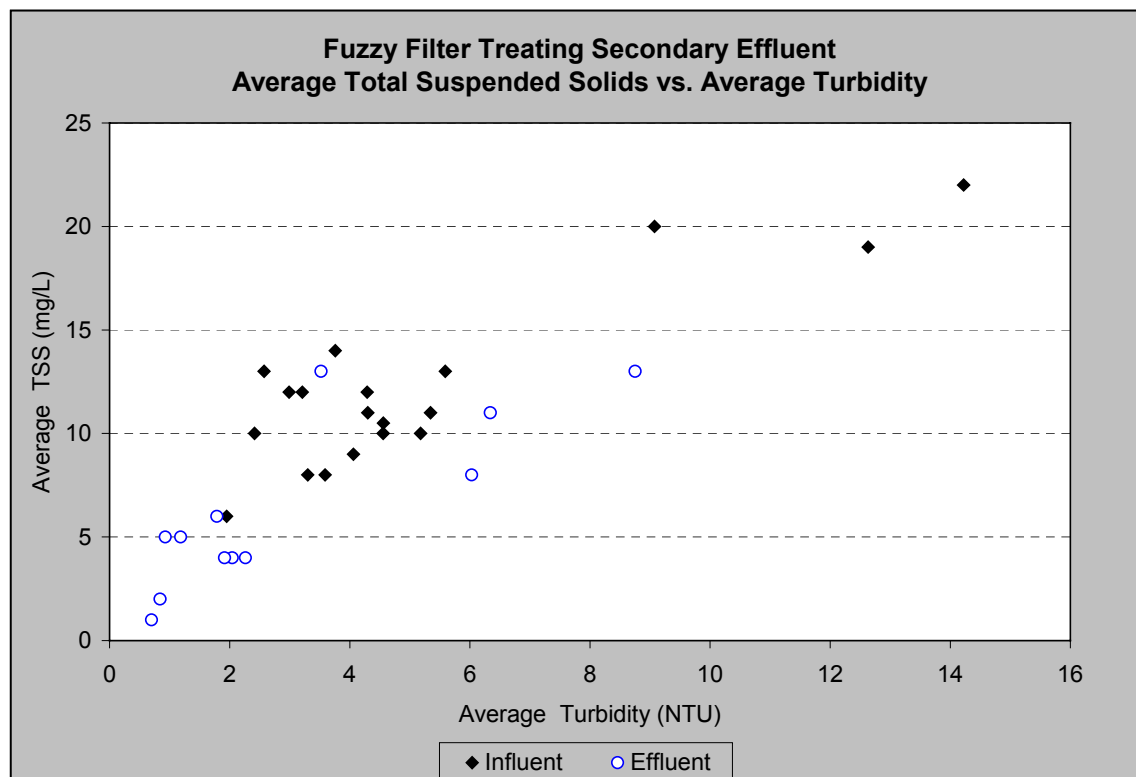


Figure 22. Fuzzy Filter Treating Secondary Effluent - No Chemical Addition. TSS Versus Average Turbidity.

As can be seen in Figure 22, there are no significant relationships between TSS and average turbidity for either influent or effluent samples. Total suspended solids measurements are taken by filtering the sample to be analyzed through a filter with a fixed opening size. Therefore, TSS concentration is a measure of the concentration of particulates that are larger than the filter size. Turbidity is measured by the light scattering of particles in the liquid and therefore affected by all particles, and especially by very small particles. The absence of a relationship between TSS and turbidity suggests that the particle size distribution of the influent likely changed throughout the period of pilot testing. A change in particle size distribution is feasible, considering operational conditions at the West Point plant during the Fuzzy Filter testing. The secondary process at the plant was stable through portions of the testing. During other parts, however, particularly during increased flow periods and periods of primary bypass, carryover

of solids in the secondary clarifier increased and bypassed primary effluent strongly influenced solids concentrations in the influent.

Fuzzy Filter performance relative to TSS removal was evaluated based on the laboratory data available. Effluent TSS as a function of influent TSS, effluent TSS as a function of TSS loading, and TSS removal as a function of TSS loading are shown in Figure 23, Figure 24, and Figure 25, respectively.

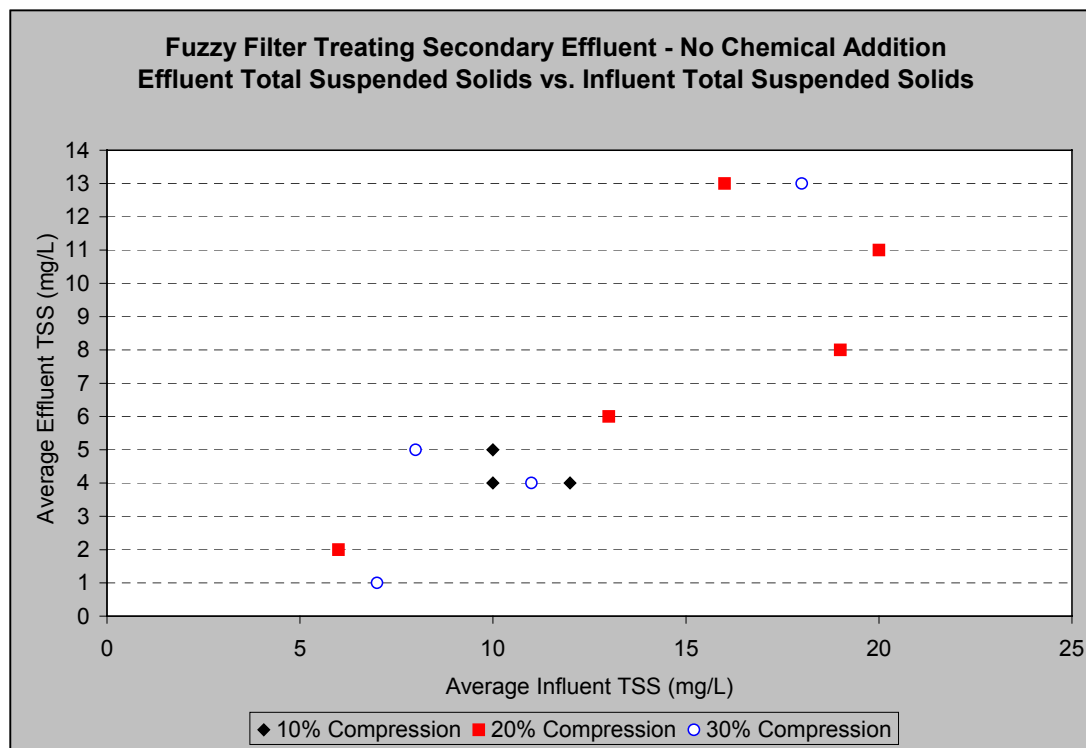


Figure 23. Fuzzy Filter Treating Secondary Effluent - No Chemical Addition. Effluent TSS Versus Influent TSS.

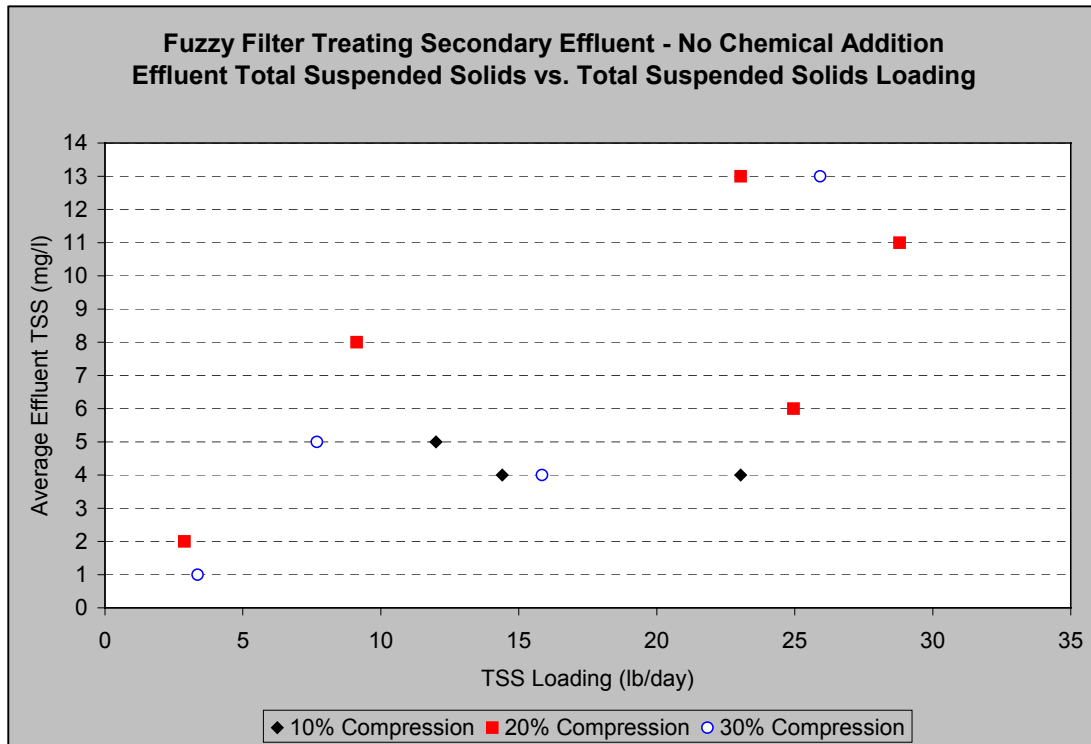


Figure 24. Fuzzy Filter Treating Secondary Effluent - No Chemical Addition. Effluent TSS Versus TSS Loading.

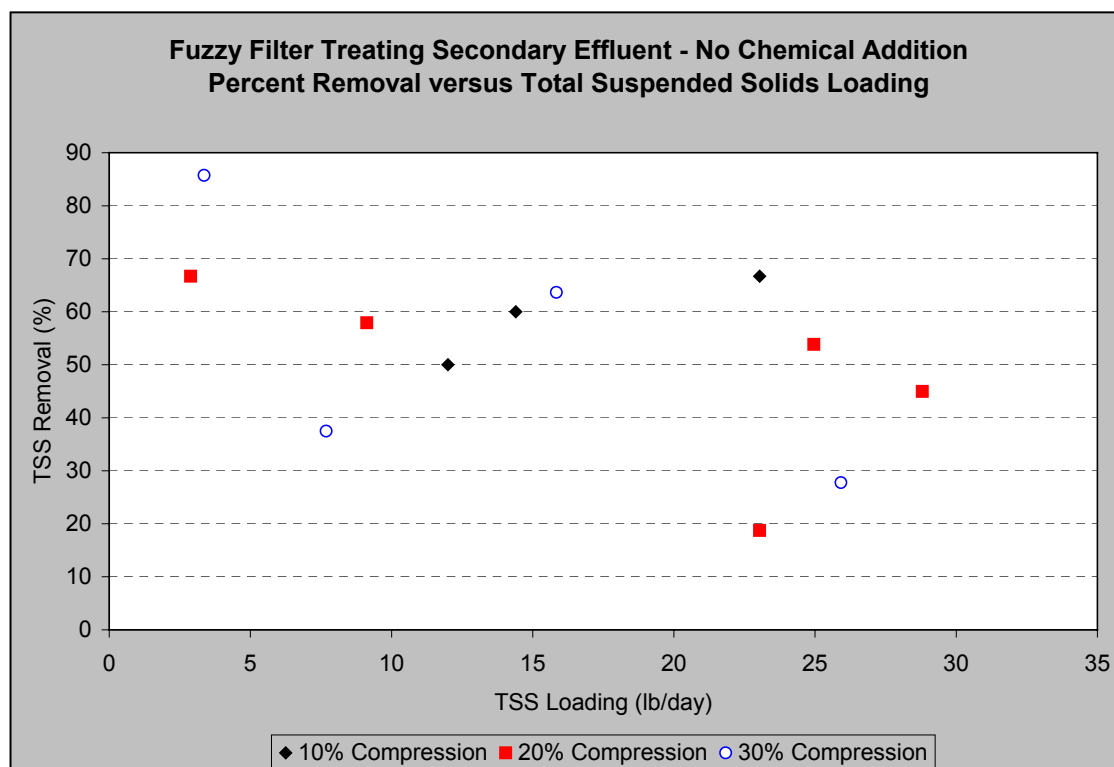


Figure 25. Fuzzy Filter Treating Secondary Effluent - No Chemical Addition. Turbidity Removal Versus Turbidity Loading

TSS loading was calculated to consider both influent TSS level and the influent flow rate. As shown in Figure 23 and Figure 24, effluent TSS showed a stronger correlation to influent TSS levels than to TSS loading. The stronger dependence of effluent TSS on influent TSS levels underscores the importance of influent characteristics on resulting effluent quality. Due to the limited number of points available for analysis, it is difficult to reasonably establish maximum influent TSS levels that will consistently yield effluent TSS at levels desired in the study. However, when considering the data that is available, an effluent concentration of 5 mg/L was achieved at influent TSS concentrations of up to 12 mg/L.

Extended Testing Performance

The Fuzzy Filter was tested at 30 gpm/ft² (120 gpm) and 20% bed compression without chemical addition for an extended period on two occasions. The first extended testing period took place between January 23, 2002, and January 31, 2002. The second took place March 15, 2002, through March 18, 2002. The hydraulic loading rate and bed compression used in the extended testing period were selected by the project team, based on the performance of the Fuzzy Filter during the operational condition testing and based on the pilot testing objectives. The highest flow rate at lowest compression that appeared to meet the criteria was chosen for the extended testing. The operational conditions used, the average influent turbidity, and the average influent TSS during each extended testing period are shown in Table 18.

Table 18. Operating Conditions During Extended Testing in Tertiary Application With No Chemical Addition

Parameter	1/23/02 – 1/31/02	3/15/02 – 3/18/02
Test Condition Number	19	44
Hydraulic Loading Rate (gpm/ft ²)	30	30
Bed Compression (%)	20	20
Wash Trigger Pressure Set Point (psi)	5.5	4.0
Average Influent TSS (mg/L)	22	7
Average Influent Turbidity (NTU)	4.9	4.4
90 th Percentile Influent Turbidity (NTU)	8.4	5.4
Maximum Influent Turbidity (NTU)	31.1	9.6
Influent Turbidity Standard Deviation (NTU)	3.9	1.0

Influent turbidity and influent TSS during the first testing period were higher than in the second. The variability of influent turbidity was also higher in the first test. High flows occurred at the West Point plant during the first run and were high enough during one period of the testing to result in bypass of a portion of the flow around the secondary treatment system (during plant flows greater than 300 MGD). Although data from the period of primary effluent bypass was not considered in the analysis of the first extended test, it is clear that increased plant flows before and after the bypass event resulted in increased turbidity levels in the influent to the Fuzzy Filter.

In the first test, the wash cycle pressure set point was set at 1.75 psi above the clean bed filter influent pressure (CBP). The resulting pressure set point for this condition was 5.5 psi. The wash pressure set point during the second test was set at 4.0 psi, a much lower pressure than in the first test to limit excursions in effluent turbidity at the end of the filter runs.

As with the operational condition testing, the periods of extended testing were broken into individual filter runs (periods between washes) to evaluate performance parameters over shorter periods. The original data set was filtered to exclude all filter runs that showed negative removal, any filter runs that were not completed prior to the end of the testing, and any filter runs during which primary effluent bypass was occurring at the West Point plant.

Turbidity Removal During Extended Runs With No Chemical Addition

Turbidity removal efficiency as a function of turbidity loading to the Fuzzy Filter during the extended testing with no chemical addition is shown in Figure 26.

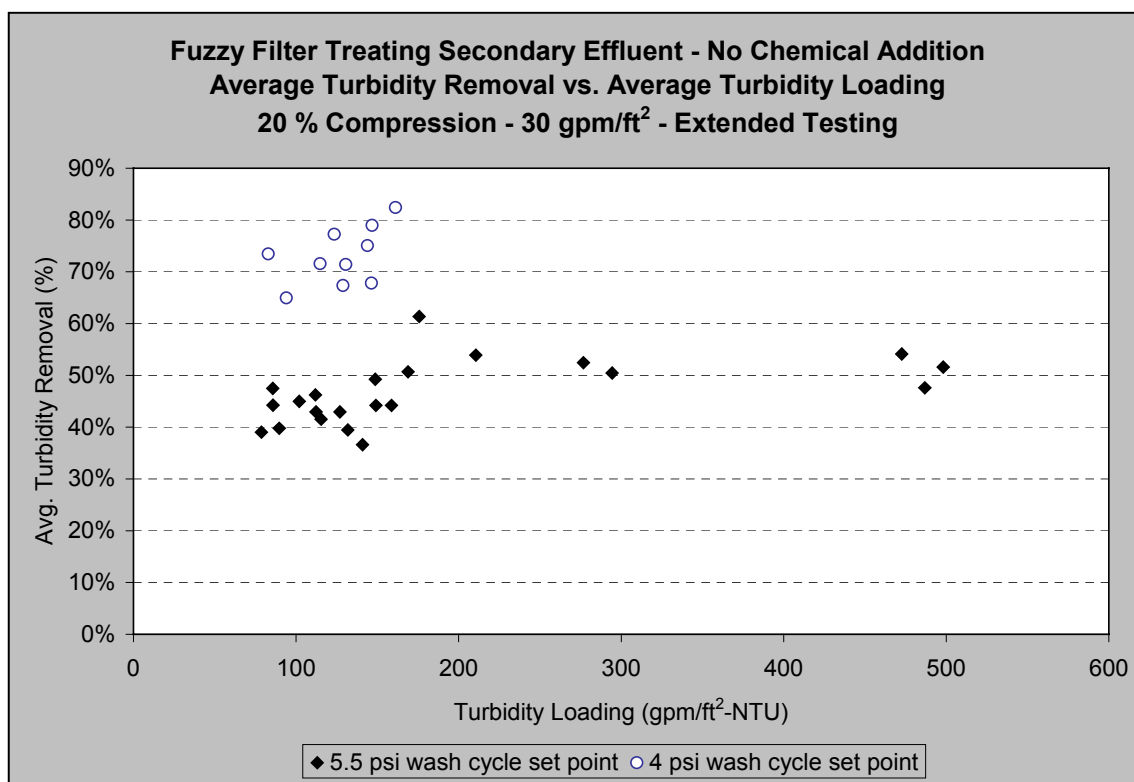


Figure 26. Fuzzy Filter Treating Secondary Effluent - No Chemical Addition. Average Turbidity Removal Versus Turbidity Loading During Extended Testing

When the wash cycle pressure set point was set at 4 psi during the second extended test, the removal efficiency was higher at equivalent turbidity loadings than when the wash cycle pressure set point was set at 5.5 psi. In the 4 psi wash pressure case, the filter runs were terminated on filter influent pressure before effluent quality deteriorated. Therefore, average removals over the shortened filter runs were higher than those in the 5.5 psi case.

Average effluent turbidity as a function of turbidity loading is shown in Figure 27.

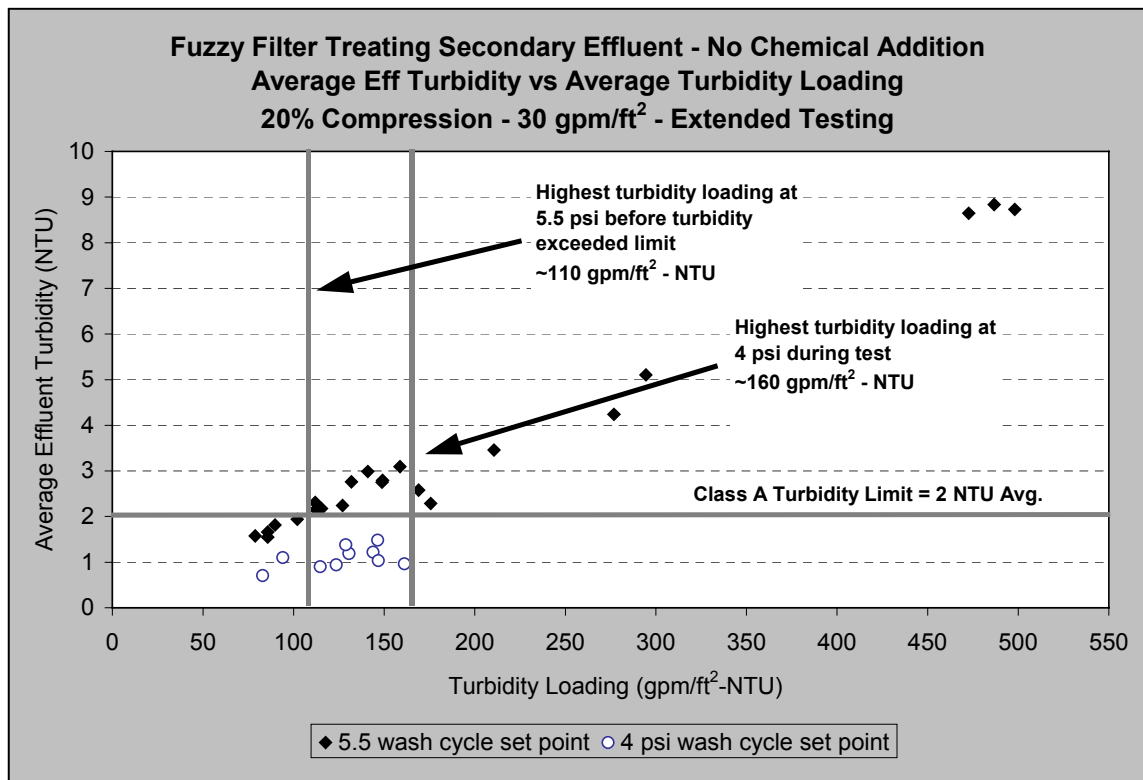


Figure 27. Fuzzy Filter Treating Secondary Effluent - No Chemical Addition. Average Effluent Turbidity Versus Turbidity Loading During Extended Testing

The decrease of the wash pressure to 4 psi decreased the resulting effluent turbidity at equivalent loading rates compared to the 5.5 psi wash case. Because the filter run was shortened, excursions in turbidity were minimized at the end of the filter run. Therefore, average effluent turbidities were lower at equivalent turbidity loadings than in the 5.5 psi case.

Based on the results shown, the maximum turbidity loading before the turbidity limit of 2 NTU was exceeded was approximately 110 gpm/ft²-NTU (3.7 NTU influent turbidity) in the 5.5 psi case. This is slightly higher than that observed during the operational condition testing phase. In the 4 psi case, the maximum influent turbidity loading recorded during the test was approximately 160 gpm/ft²-NTU (5.3 NTU influent turbidity). The average effluent turbidities for all of the runs in the 4 psi case were less than 2 NTU, suggesting that higher influent turbidities may be permissible without sacrificing the desired effluent quality. Alternately, at turbidity loading values in the range tested, the wash pressure may be increased to higher levels to extend the run times without exceeding the turbidity limit.

Filter Run Times During Extended Runs With No Chemical Addition

Filter run times as a function of the influent turbidity loading during the extended testing periods is shown in Figure 28.

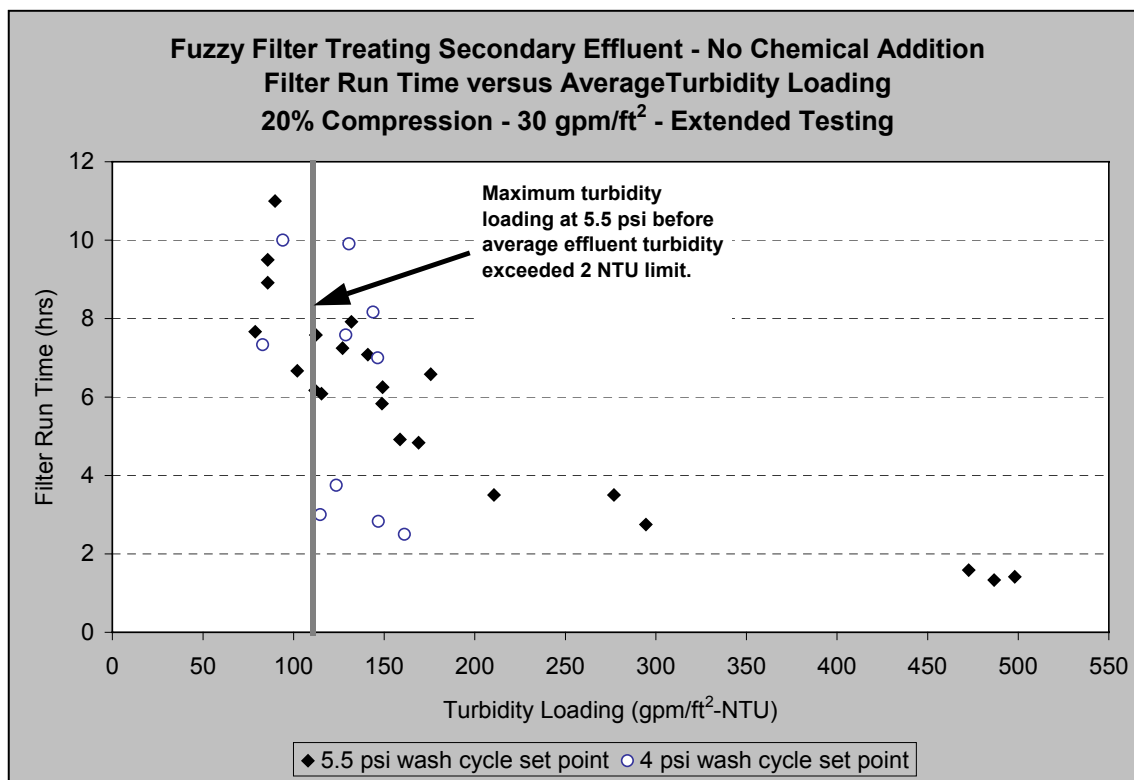


Figure 28. Fuzzy Filter Treating Secondary Effluent - No Chemical Addition. Filter Run Time Versus Turbidity Loading During Extended Testing.

The reduction in wash cycle pressure set point resulted in lower run times during some of the filter runs. However, in some filter runs, the 4 psi filter run times were equivalent to or higher than those observed for the 5.5 psi case. Filter run times for the 5.5 psi case were longer than six hours at turbidity loadings less than the maximum loading when desired effluent quality was achieved. In the 4 psi case, the filter run times for several of the runs were very short, between two and four hours. Such short run times would make full-scale implementation of the Fuzzy Filter questionable. However, as stated previously, some lengthening of the filter run could be achieved in these instances by increasing the wash cycle set point.

The results presented in this section suggest that the reduction of wash cycle pressure set point of the Fuzzy Filter can have a beneficial effect on the observed effluent turbidity. Reduction of the wash pressure set point from 5.5 psi to 4 psi allowed influent turbidity from 3.7 NTU to at least 5.3 NTU without exceeding the effluent turbidity limit. However, reduction in the wash cycle pressure does have the potential to decrease filter run times. Based on these observations, the wash pressure set point should be used to optimize Fuzzy Filter performance at a given influent loading rate and bed compression.

Reliability Considerations

Statistical plots of Fuzzy Filter performance for the two extended testing periods are shown in Figure 29 and Figure 30

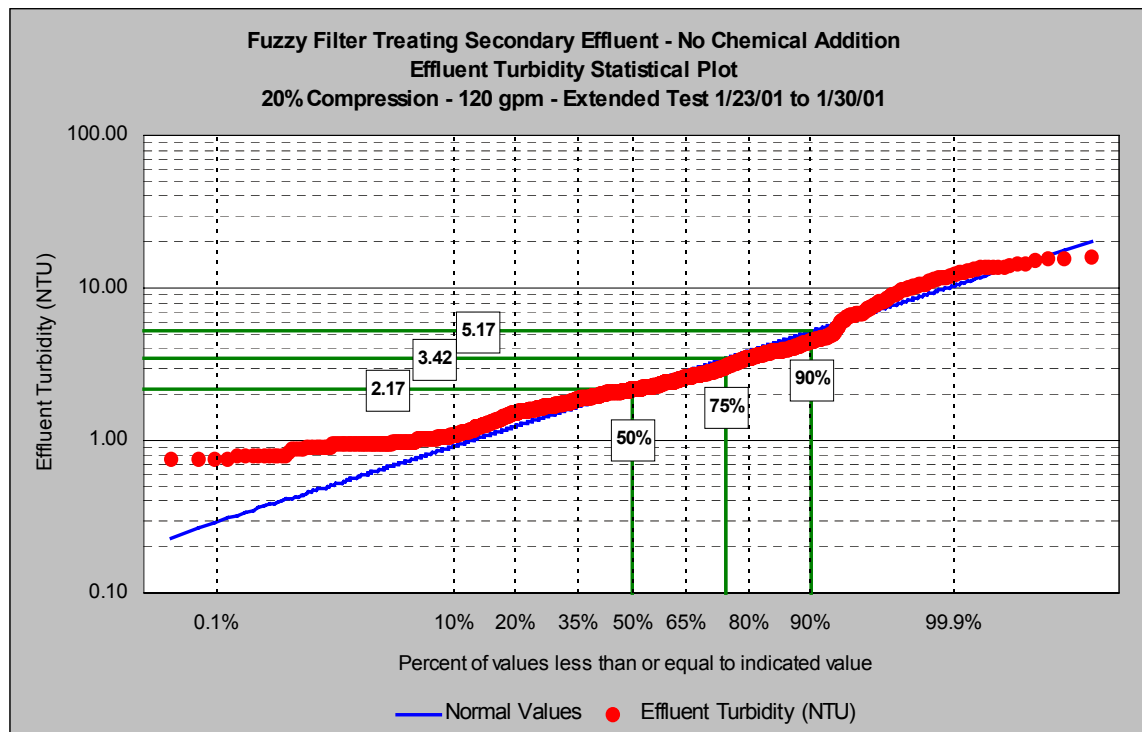


Figure 29. Fuzzy Filter Treating Secondary Effluent - No Chemical Addition. Statistical Plot of Extended Testing Period 1/23/01 - 1/30/01

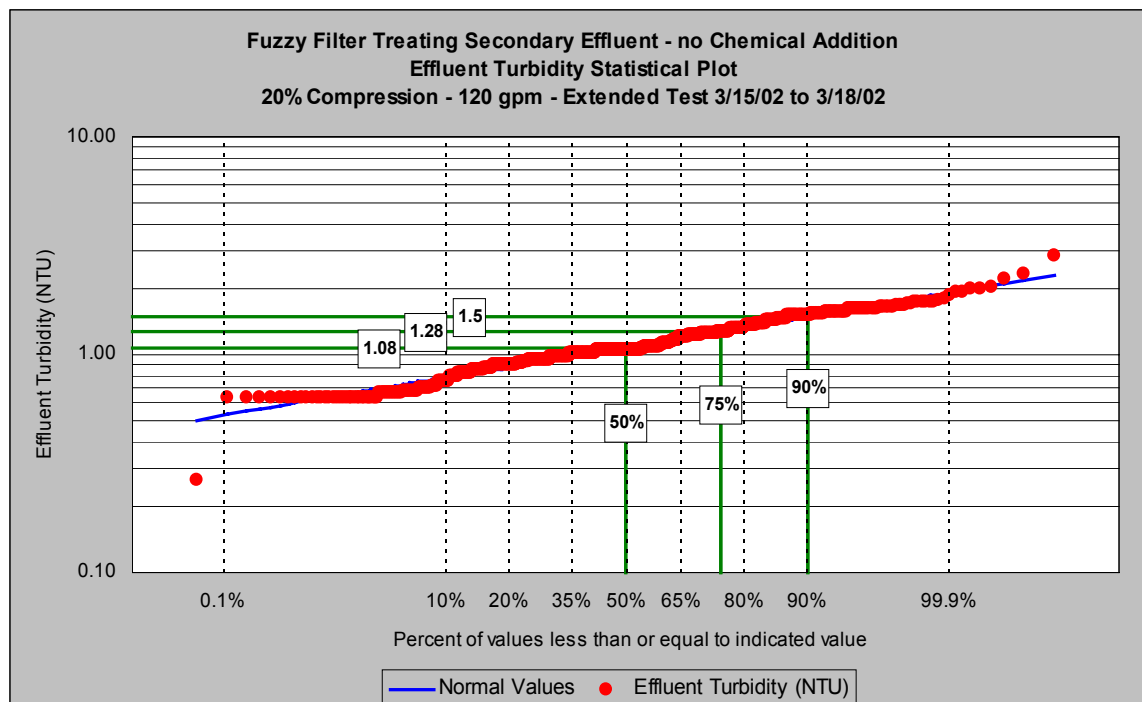


Figure 30. Fuzzy Filter Treating Secondary Effluent - No Chemical Addition. Statistical Plot of Extended Testing Period 3/15/02 - 3/18/02

The Fuzzy Filter produced effluent with a much lower turbidity and less variability during the second extended testing period. During the first test, effluent turbidity at the 90th percentile did not meet the pilot objectives. During the second test, effluent turbidity at the 90th percentile was less than the target of 2 NTU. There are likely several reasons for the improved performance during the second test. First, the turbidity in the influent during the first test was higher than in the second (see Table 18). Second, the wash cycle pressure set point was lower in the second test, preventing excursions during the latter part of the filter runs. The results from the second extended period support the use of the Fuzzy Filter for filtration of secondary effluent under relatively consistent influent conditions.

Tertiary Treatment With Chemical Addition

Jar Testing with Alum

The results of preliminary jar testing performed with alum are summarized in Table 19

Table 19. Alum Jar Test Results for Secondary Effluent

Alum Dose (mg/L)	Supernatant Turbidity (NTU)	Supernatant TSS (mg/L)	Supernatant t-P (mg/L)	Supernatant PO ₄ (mg/L)	Alum added per PO ₄ removed (mg alum/mg PO ₄)	Aluminum added per PO ₄ removed (mg-Al/mg PO ₄)
0	3.7	3	1.34	1.12		
5	3.18	5	1.32	0.94	27.8	2.5
10	3.78	6	1.47	0.66	21.7	2.0
20	4.68	11	1.34	0.19	21.5	1.9
30	2.92	13	1.07	0.1	29.4	2.6
50	2.64	11	0.53	0.035	46.1	4.1
70	1.37	7	0.24	0.018	63.5	5.7

Notes:

Alum added had chemical formula $Al_2(SO_4)_3 \cdot 14 H_2O$. Dosages expressed in terms of alum based on entire chemical formula.

A dose of 30 mg/L was selected for the initial testing based on the reduction in phosphate (PO₄) achieved. As can be seen from the table, an alum dose of 30 mg/L reduced the PO₄ to 0.10 mg/L. Based on the original difference in total phosphorus (t-P) and PO₄ with no chemical dose, this reduction would be sufficient to reduce the t-P to less than 0.5 mg P/L. The addition of 30 mg/L alum in the jar tests resulted in visible floc formation. However, the floc did not settle to levels observed after addition of 50 mg/L and 70 mg/L alum. It was expected that the Fuzzy Filter would effectively filter the particles observed in the testing at the lower dosage.

The alum solution used in the testing was approximately 9% aluminum based on molecular weight. Jar tests were not conducted for PACl. The PACl used in the testing contained 9.5% aluminum based on molecular weight. Based on these similar percentages of aluminum, the 30 mg/L dose was also used for PACl. At a dosage of 30 mg/L, the resulting increase in TSS in

the influent to the Fuzzy Filter is approximately 10.5 mg/L, based on theoretical calculations of precipitate formation.

Analysis of Performance with Different Coagulant Dosages and Types

The Fuzzy Filter was tested under many different conditions during tertiary treatment with chemical addition. The Fuzzy Filter performance with chemical addition was evaluated based on comparisons of:

- Performance with alum addition versus PACl addition at a 30 mg/L dosage rate, 20 gpm/ft² hydraulic loading rate, and 20% bed compression.
- Different operational conditions with PACl addition at a 30 mg/L dosage rate.
- Performance with different PACl dosages at 30 gpm/ft² hydraulic loading rate and 10% bed compression.
- Performance with and without chemical addition.

Similar to the methodology used to evaluate Fuzzy Filter performance without chemical addition, test results for chemical testing were separated into individual filter runs between wash cycles. The operational results were then averaged over each filter run. Filter runs with negative turbidity removal, incomplete filter runs, and runs during which primary effluent bypass occurred at the West Point plant were deleted from the data set.

Alum Versus PACl

Comparison of turbidity removal efficiency with a coagulant dosage rate of 30 mg/L of both alum and PACl at 20 gpm/ft² L and 20% compression as a function of turbidity loading is shown in Figure 31.

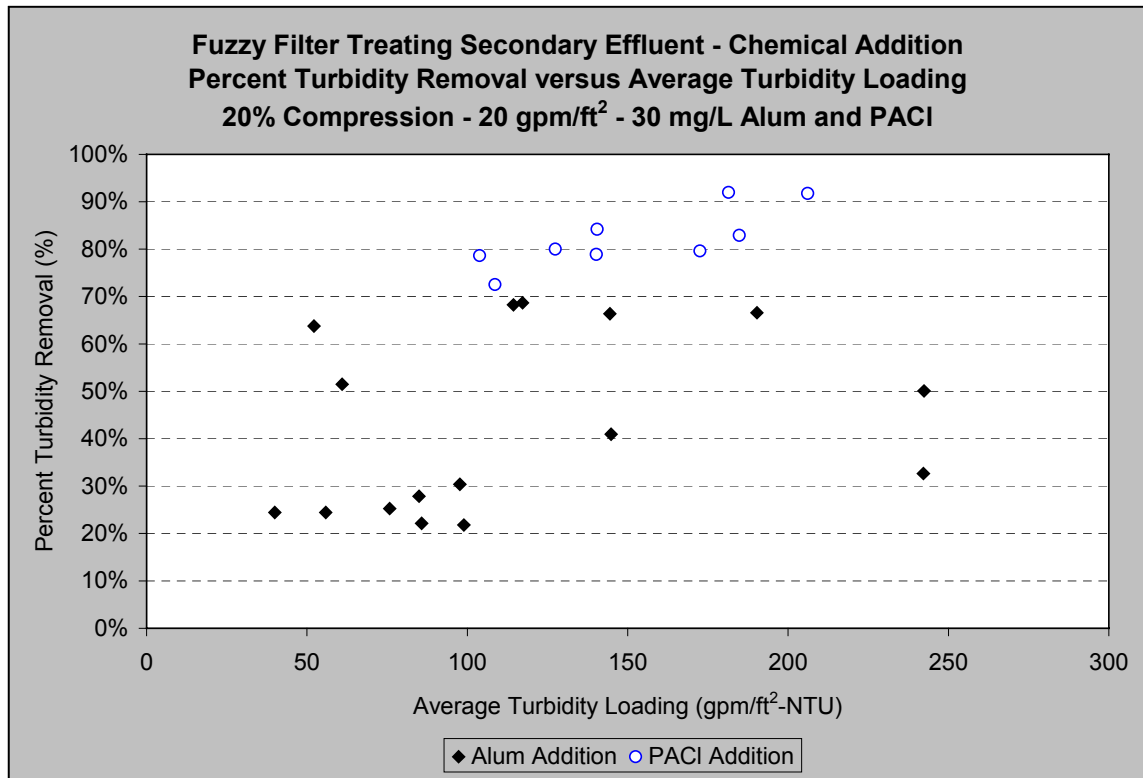


Figure 31. Fuzzy Filter Treating Secondary Effluent with Chemical Addition. Comparison of Alum and PACl Turbidity Removal at 20% Compression, 20 gpm/ft², and Chemical Dosage of 30 mg/L.

The influent turbidity loading shown in the graph is based on turbidity measurements taken upstream of the location of chemical addition. The addition of PACl resulted in higher turbidity removals than did addition of alum. This increase in removal efficiency is attributed to a faster reaction time for the PACl and more effective flocculation of small particles prior to filtration in the Fuzzy Filter.

The existing facilities provided limited detention time upstream of the Fuzzy Filter (i.e., two minutes) and no external mixing was provided at the point of injection. Since PACl is partially hydrolyzed, its reaction time, without external mixing, is shorter than that of alum, and therefore more flocculation with PACl, occurred upstream of the filter. The removal efficiency with PACl addition was higher than when no chemical was added, further supporting the observation that some flocculation of small particles had taken place prior to filtration.

Figure 32 shows the average effluent turbidity as a function of influent turbidity loading for the above-mentioned conditions.

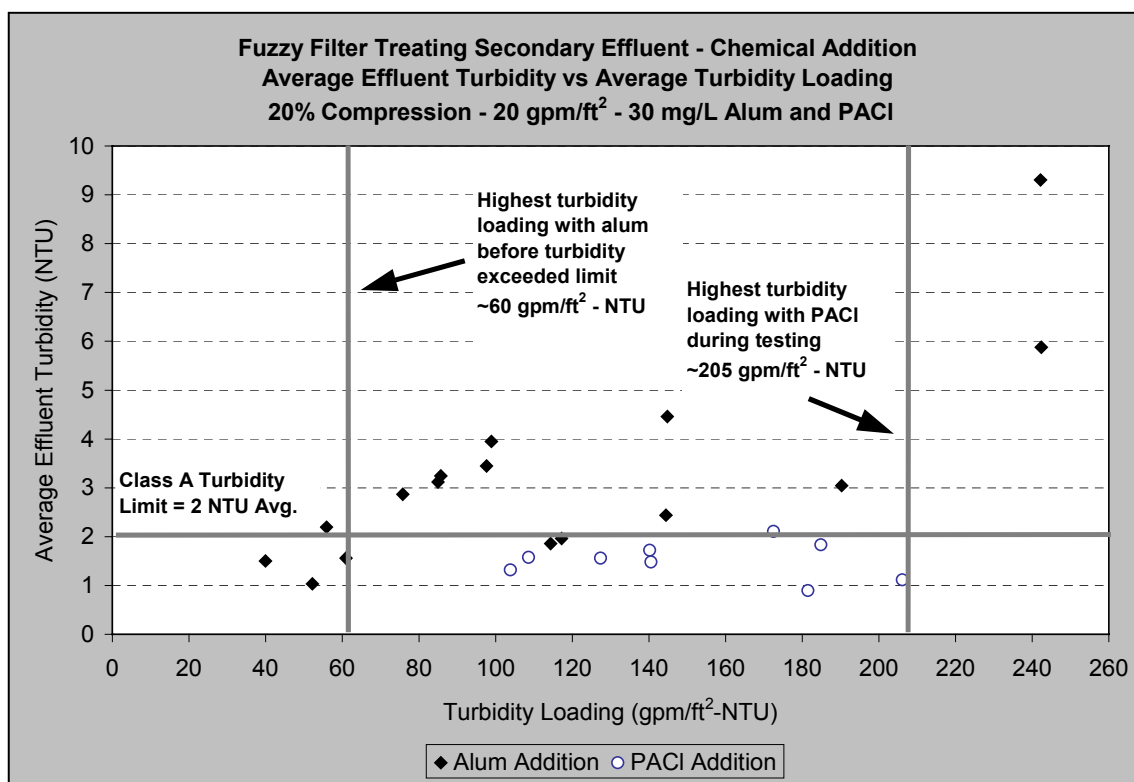


Figure 32. Filter Treating Secondary Effluent with Chemical Addition. Average Effluent Turbidity Versus Turbidity Loading at 20% Compression, 20 gpm/ft², and 30 mg/L PACl and Alum Addition.

Addition of PACl resulted in lower effluent turbidities than addition of alum at equivalent turbidity loadings. Greater removal with PACl is thought to be due to a greater level of flocculation after chemical addition. Because all of the data shown is taken from testing at the same influent loading rate (20 gpm/ft²) the trends shown are the same as those that would result if turbidity was plotted against influent turbidity. In contrast to data presented for tertiary testing without chemical addition (Figure 16, Figure 17, and Figure 18), the addition of coagulants decreases the influence of influent turbidity on the effluent quality. Because particle sizes are increased by coagulation, the dependence of the Fuzzy Filter on the characteristics of the influent is reduced.

The highest turbidity loading observed during testing with PACl corresponds to an average influent turbidity of approximately 10 NTU. This is considerably higher than average values during the second extended testing period with no chemical addition, further supporting the observation that chemical addition reduces the influence of influent characteristics on effluent quality. The highest turbidity loading before 2 NTU was exceeded for alum addition was significantly less than the testing with PACl, corresponding to a maximum influent turbidity of approximately 3 NTU.

The Fuzzy Filter performed less favorably with alum addition, possibly due to incomplete flocculation prior to filtration. The limited detention time available after chemical addition (two minutes) likely contributed to the lower performance observed. The performance of the Fuzzy Filter with alum addition was also less favorable relative to when no chemical was added. The addition of alum increased the solids loading on the Fuzzy Filter, but likely without the formation of flocculated solids that would be removed effectively in the filter.

Filter run times that resulted with PACl and alum addition at the operating conditions discussed above are shown in Figure 33.

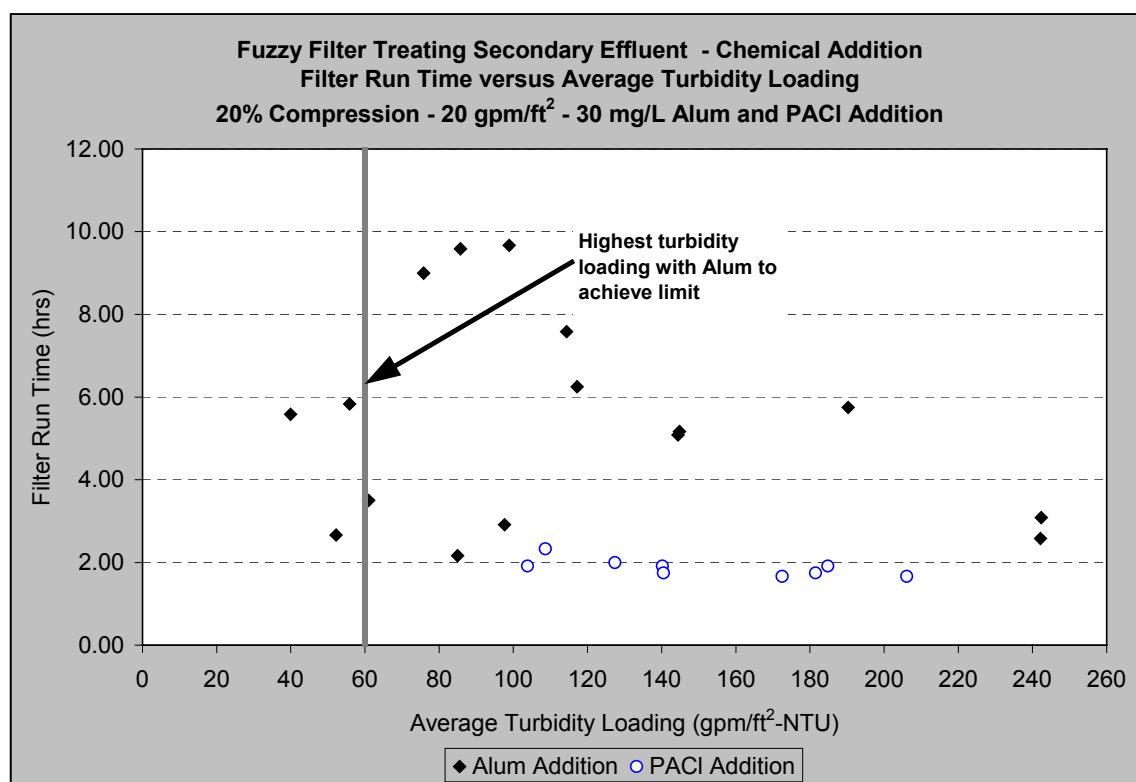


Figure 33. Fuzzy Filter Treating Secondary Effluent with Chemical Addition. Run Time Versus Turbidity Loading at 20% Compression and 20gpm/ft² with 30 mg/L Alum and PACl Addition.

The addition of PACl resulted in significantly lower run times at similar turbidity loadings relative to alum addition. The reduction in run time observed with the addition of PACl further supports the observation that PACl addition resulted in more effective coagulation/flocculation of influent particles relative to alum. The run times with PACl addition were relatively short (i.e., two hours). Run times of this duration are likely not feasible for full-scale application.

Composite samples of influent and effluent were taken during the runs shown in Figure 31, Figure 32, and Figure 33. TSS and phosphorus removal and effluent concentrations achieved with PACl and alum addition at 20 gpm/ft² and 20% compression are shown in Table 20.

Table 20. TSS and Phosphorus Removal in Treatment of Secondary Effluent with PACl and Alum Addition at 30 mg/L

Run #	Coagulant	TSS Removal (%)	Effluent TSS (mg/L)	TP Removal (%)	Effluent TP (mg/L)	PO ₄ Removal (%)	Effluent PO ₄ (mg/L)
20	Alum	26	17	36	1.44	40.9	1.36
31	Alum	27	8	34	1.15	74.5	0.47
33	PACl	53	8	100	ND	78.9	0.36

NOTES:

Fuzzy Filter operated at 20 gpm/ft² influent loading rate and 20% compression.

Calculated TSS removal does not include increase in solids due to chemical addition. TSS samples for the influent were taken upstream of the chemical feed point.

The addition of PACl resulted in greater removal of TSS, total phosphorous (t-P), and PO₄ relative to alum. This observation is consistent with the trends shown in the previous figures. The greater removal is likely due to the partially hydrolyzed nature of PACl and a quicker reaction time prior to the Fuzzy Filter.

Performance with PACl Under Different Operational Conditions

Several tests were conducted at different operating conditions with PACl addition at 30 mg/L and a 4 psi wash-cycle pressure set point. For these tests, the wash cycle pressure set point was set to 4 psi, rather than 1.75 psi, above the clean bed influent pressure to prevent excursions in effluent turbidity at the end of the filter run. For this analysis, only runs when the wash pressure was set at 4 psi were considered. Figure 34, Figure 35, and Figure 36 are graphs of turbidity removal efficiency, average effluent turbidity, and run time as a function of influent turbidity loading.

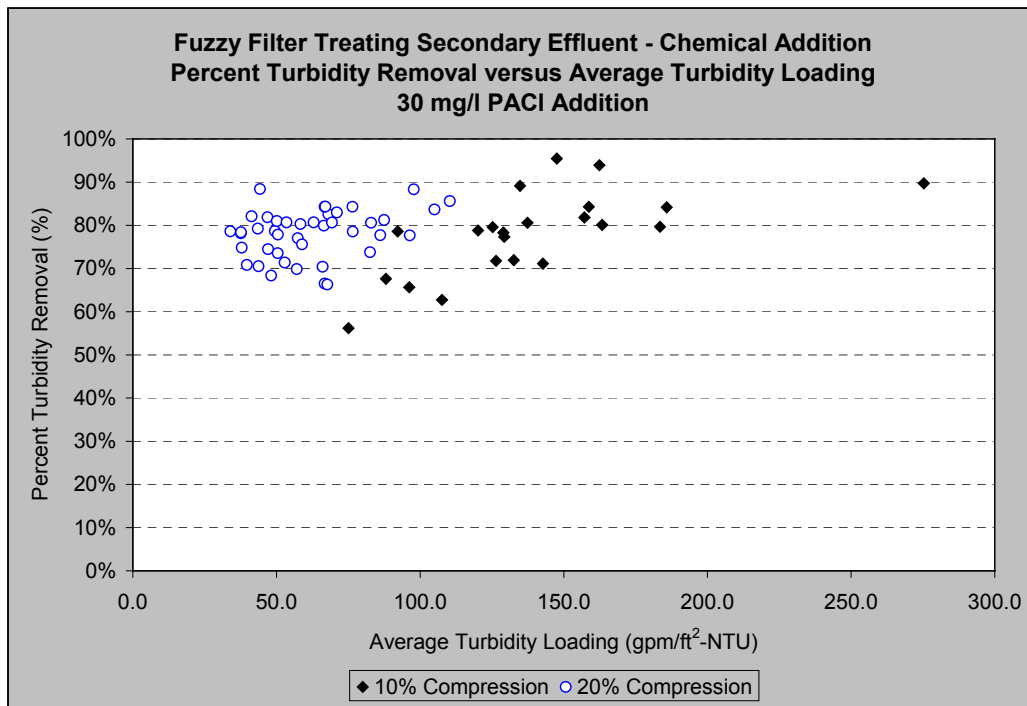


Figure 34. Fuzzy Filter Treating Secondary Effluent with Chemical Addition. Average Turbidity Removal Versus Influent Turbidity Loading with Addition of PACI at 30 mg/L and a Wash Cycle Pressure of 4 psi

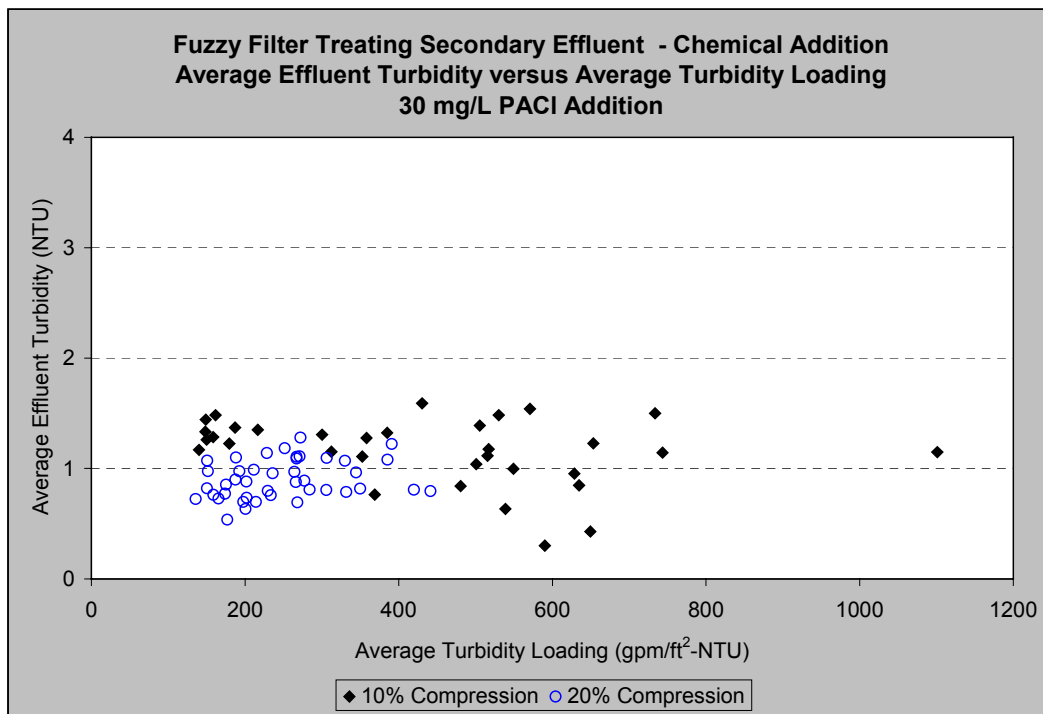


Figure 35. Fuzzy Filter Treating Secondary Effluent with Chemical Addition. Average Effluent Turbidity Versus Influent Turbidity Loading with PACI Addition at 30 mg/L and a Wash Cycle Pressure of 4 psi

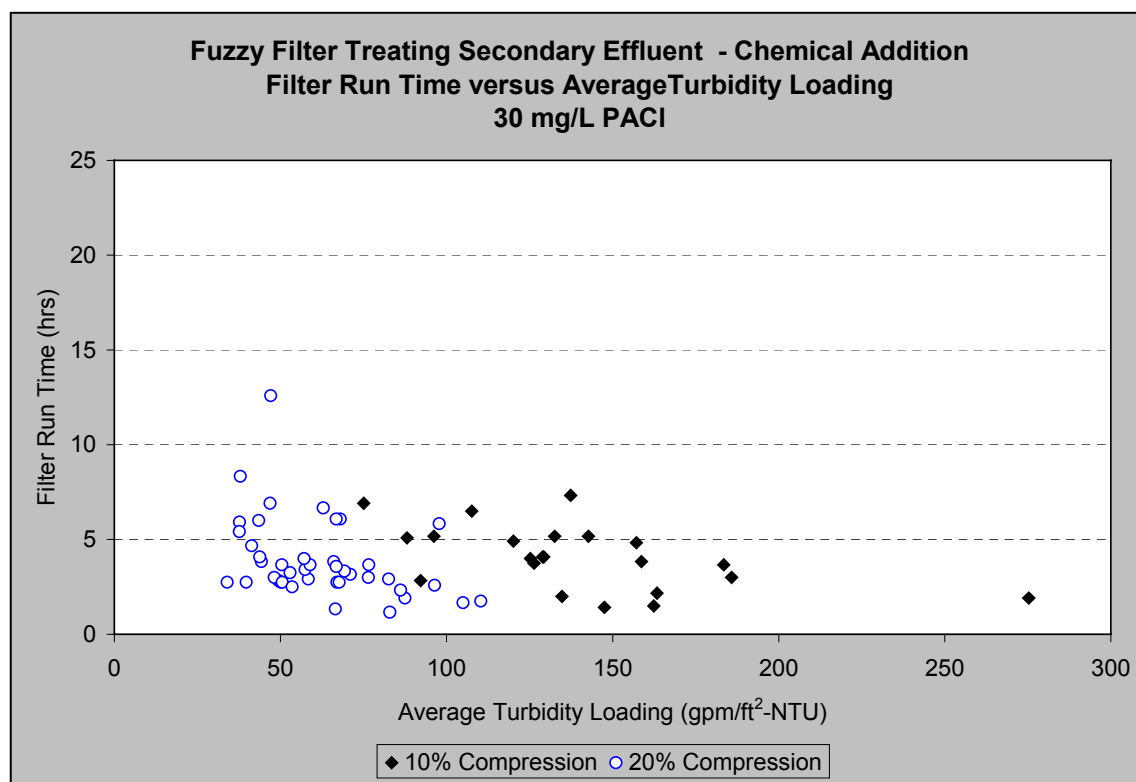


Figure 36. Fuzzy Filter Treating Secondary Effluent with Chemical Addition. Run Time Versus Influent Turbidity Loading with Addition of PACl at 30 mg/L and Wash Cycle Pressure of 4 psi

Operation of the Fuzzy Filter at 20% compression resulted in higher removal efficiencies and lower average effluent turbidity than at 10% compression at lower turbidity loading rates. However, at higher turbidity loading rates, operation at 10% compression achieved equivalent removals and average effluent turbidity levels relative to lower loading conditions. With the exception of one isolated run, the average effluent turbidity was below 2 NTU. Although operational results were not obtained at higher loading rates for 20% compression, the consistency of effluent turbidity with increasing turbidity loading across both compressions suggests that the coagulant addition reduces the influence of the influent characteristics on effluent turbidity. Run times for 20% compression were lower than in the 10% compression runs, likely due to greater solids capture and resultant higher rates of influent pressure increase.

Laboratory results for the cases considered in the above discussion are shown in Table 21.

Table 21. TSS and Phosphorus Removal in Treatment of Secondary Effluent with PACl Addition at 30 mg/L Under Different Operating Conditions

Test Condition #	Bed Compression	Hydraulic Loading Rate (gpm)	TSS Removal (%)	Effluent TSS (mg/L)	t-P Removal (%)	Effluent t-P (mg/L)	PO ₄ Removal (%)	Effluent PO ₄ (mg/L)
35	10	40	17	9	56	0.61	NA	NA
38	10	80	11	8	56	0.92	56	0.92
39	10	60	NA	NA	6	1.94	41	1.27
40	10	100	55	5	44	0.65	48	0.57
42	10	120	60	4	37	1.19	40	0.98
33	20	80	64	7	NA	NA	NA	NA
34	20	40	NA	NA	NA	1.28	69	0.43
36	20	60	50	7	45	1.09	37	1.05
37	20	80	50	6	46	1.23	62	0.75

NOTES:

Results shown from testing of Fuzzy Filter with 30 mg/L PACl dose

Calculated TSS removal does not include increase in solids due to chemical addition. TSS samples for the influent were taken upstream of the chemical feed point.

No improvement in TSS removal or t-P removal was achieved by increasing compression from 10% to 20%. While some reduction in effluent t-P was observed, an insufficient amount of coagulant was added during these tests (30 mg/L) to effectively remove the majority of the PO₄.

Performance with PACl at Different Chemical Dosages

The Fuzzy Filter was tested with addition of PACl at different dosages under similar feed rates and a bed compression of 10%. Average effluent turbidity and run time as a function of influent turbidity loading are shown in Figure 37 and Figure 38.

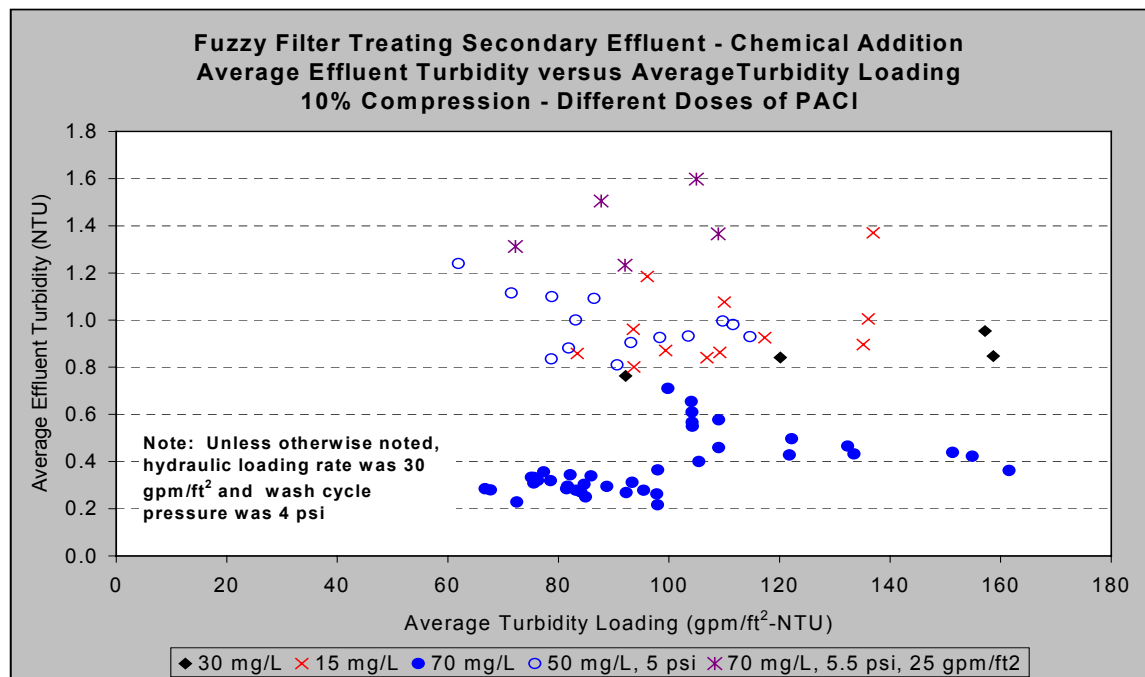


Figure 37. Fuzzy Filter Treating Secondary Effluent with Chemical Addition. Effluent Turbidity Versus Turbidity Loading with Different PACl Doses at 10% Compression and 30 gpm/ft²

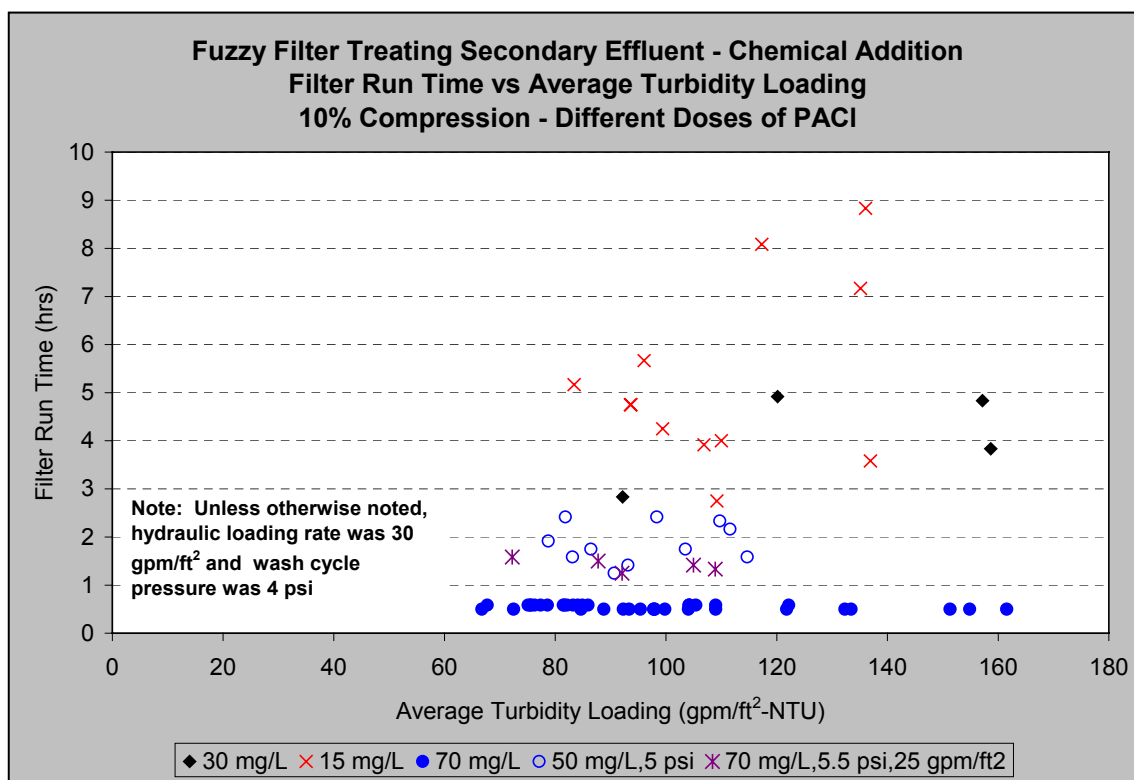


Figure 38. Fuzzy Filter Treating Secondary Effluent with Chemical Addition. Run Time Versus Turbidity Loading Rate with Different PACl Doses at 30 gpm/ft² and 10% Compression

The average effluent turbidity was below 2 NTU for all doses and operating conditions tested. Influent turbidities ranged from 2 NTU to 9 NTU. The addition of 70 mg/L PACl resulted in the lowest average effluent turbidity. Adding 70 mg/L of PACl and increasing the filter backwash trigger pressure to 5.5 psi resulted in significantly higher effluent turbidities. This increase in effluent turbidity as a result of changed wash-cycle trigger pressure is likely due to higher effluent turbidities toward the end of the filter runs.

The higher dosages of PACl resulted in significantly lower run times, even when the backwash cycle trigger pressure was increased to 5.5 psi. At lower dosages, run times were generally higher, with the highest run times at a dosage of 15 mg/L PACl. During several runs at 15 mg/L PACl, the run times were above six hours while maintaining effluent turbidity well below 2 NTU. This suggests that small amounts of chemical addition, while not enough to remove phosphorus to desired levels, can reduce effluent turbidity without major impacts to run time.

Laboratory data for the filter runs during the testing described in the previous section is shown in Table 22.

Table 22. TSS and Phosphorus Removal and Effluent Concentrations with Different PACl Doses and Operation at 30 gpm/ft² and 10% Compression

Test Condition #	Coag. Dose / Wash Pressure	TSS Removal (%)	Effluent TSS (mg/L)	t-P Removal (%)	Effluent t-P (mg/L)	PO ₄ Removal (%)	Effluent PO ₄ (mg/L)
42	30 / 4 psi	60	4	37	1.19	40	0.98
43	15 / 4 psi	82	2	NA	NA	NA	NA
45	15 / 4 psi	50	4	4	1.6	21	1.2
46	70 / 4 psi	NA	NA	98	0.02	99	0.01
47	50 / 5 psi	33	8	53	0.76	78	0.33
48	50 / 5 psi	NA	NA	33	1.31	64	0.64
49	70 / 5.5 psi	NA	NA	59	0.77	100	ND

Notes

Calculated TSS removal does not include increase in solids due to chemical addition. TSS samples for the influent were taken upstream of the chemical feed point.

The addition of 70 mg/L PACl led to the effective removal of t-P through the filter. However, as was discussed before, the run times for the filter were very short, likely due to the increased solids loading and removals resulting from that addition of PACl. While addition of 15 mg/L PACl did not result in appreciable removals of t-P, the reduction of TSS observed during this test was greater than with the other chemical doses. Addition of a small amount of coagulant provided some flocculation, while having only a small effect on the solids loading to the filter.

When 70 mg/L of PACl was added to the influent while operating the filter at a 5.5 psi backwash pressure trigger, the t-P removals were much lower than when the filter was operated at a 4 psi backwash pressure trigger. Consistent with the turbidity removal trends observed in Figure 37 and Figure 38, the higher wash cycle trigger pressure resulted in higher levels of turbidity (and therefore solids) in the effluent.

A comparison of effluent and influent turbidity with and without chemical addition is shown in Figure 39.

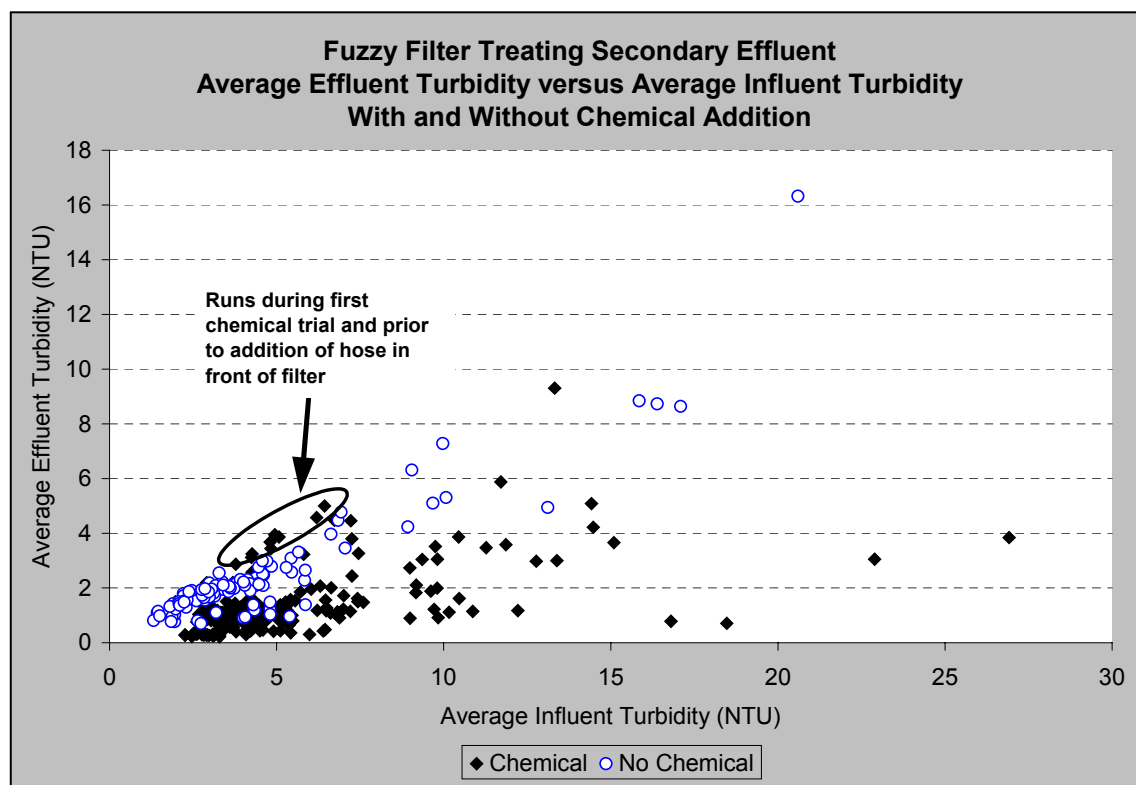


Figure 39. Fuzzy Filter Treating Secondary Effluent. Influent Versus Effluent Turbidity With and Without Chemical Addition. Data for Both Alum and PACl.

The addition of coagulant ahead of the Fuzzy Filter decreased the impact of influent turbidity on effluent turbidity. Coagulation improved the particle capture in the Fuzzy Filter. Considering all filter runs, the maximum influent turbidity that consistently resulted in effluent turbidities at or below 2 NTU without chemical addition was approximately 3 NTU. With chemical addition, the maximum influent turbidity that consistently resulted in effluent turbidity below 2 NTU was approximately 5.5 NTU (excluding the initial alum runs).

Evaluation of Pilot Results and Conclusions

Primary Treatment

The performance of the Fuzzy Filter in the treatment of primary influent relative to the performance objectives established by the project team is summarized in Table 23.

Table 23. Comparison of Performance Goals and Pilot Test Results for Primary Treatment

Performance Goal	Fuzzy Filter Performance
♦ Filter Run Times Greater Than 24 Hours	<ul style="list-style-type: none"> ♦ Breakthrough of solids was observed shortly after the wash cycle (i.e., less than one hour). ♦ Due to breakthrough, no automatic backwashes were initiated.
♦ >80 % TSS Removal	<ul style="list-style-type: none"> ♦ Results suggesting >75% removal for some conditions are questionable. Settling of solids within the effluent sample bucket and breakthrough of solids in filter were observed.
♦ Wash Cycle Waste <8% of Treated Flow	<ul style="list-style-type: none"> ♦ Filter performance was limited by high solids loading of primary influent. ♦ Filter runs were very short and wash cycle waste percentages exceeded the goal.
♦ Zero Long-Term Buildup of Clean Bed Headloss	<ul style="list-style-type: none"> ♦ No extended testing was performed on the Fuzzy Filter in treatment of primary influent. ♦ Visual observations by operations staff suggest that media can be cleaned effectively.

Using the Fuzzy Filter to treat primary influent has not been tested before. Prior tests were focused primarily on treatment of secondary effluent. The two are quite different. In primary influent, the particle size is likely larger than that for secondary effluent. The nature of the solids is also quite different, with a greater tendency to stick or gum due to higher grease content in the water. but most important, the solids loading rate is much higher in a primary application; the solids loading rates are 10 to 15 times higher than in a secondary application.

The Fuzzy Filter does not appear to be suitable for treatment of primary influent under the conditions tested at West Point. Breakthrough of solids was observed after short filter run times (i.e., less than one hour). This breakthrough was due to the high solids loading, the nature of the primary influent solids, and the restricted solids capture in the filter media bed. As the filter was loaded, the larger primary solids rapidly accumulated at the very bottom of the media bed. After this rapid accumulation, the pore space available to flow was clogged and flow began to bypass the filter bed along the sidewalls. Unexpectedly, blinding of the bottom layer of media did not result in sufficient filter influent pressure buildup to trigger a backwash. The short-circuiting of influent flow around the media bed led to an increase in turbidity, and likely suspended solids, in the effluent. Since very little solid material was being removed from the flow, very little solid material was being stored within the media bed.

The use of the Fuzzy Filter for treatment of primary influent is not recommended based on the observed performance of the pilot unit with West Point plant primary influent. Due to clogging of the bottom layers of the filter, there was very little penetration into the media bed.

Therefore, filter run times would need to be very short (i.e., less than one hour) to prevent solids breakthrough. The resulting high frequency of backwash would necessitate the use of a large number of filter units in full-scale application. In addition, a high volume of backwash residual would be generated, significantly increasing loadings to other treatment processes.

Tertiary Treatment With No Chemical Addition

A comparison of performance goals and results for tertiary treatment with no chemical addition is shown in Table 24.

Table 24. Comparison of Performance Goals and Results for Tertiary Treatment with No Chemical Addition

Performance Goal	Fuzzy Filter Performance
◆ Effluent TSS < 5 mg/L 90 th percentile	<ul style="list-style-type: none"> ◆ TSS removal efficiency and effluent concentrations varied with influent TSS concentration. ◆ An average TSS of 5 mg/L was achieved when influent TSS concentrations were below 12 mg/L. ◆ Extended testing under optimum operation was not of sufficient duration to evaluate 90th percentile TSS effluent values.
◆ Effluent Turbidity < 2 NTU, 90 th percentile	<ul style="list-style-type: none"> ◆ Under extended testing conditions (30 gpm/ft², 20% compression, 4 psi wash cycle pressure set point) effluent turbidity was less than 2 NTU, 90th percentile at an average influent turbidity of 4.4 NTU and a maximum influent turbidity of 10 NTU.
◆ Effluent t-P < 0.5 mg/L 90 th percentile	<ul style="list-style-type: none"> ◆ An effluent t-P of 0.5 mg/L was not met without chemical addition under any of the test conditions.
◆ Compliance with Washington State Class A Standards	<ul style="list-style-type: none"> ◆ Process Requirements: Without the ability for chemical addition, the Fuzzy Filter does not meet Washington State Class A requirements. Oxidation and disinfection were provided upstream of the Fuzzy Filter during this study. ◆ Disinfection Requirements: Removal of Total Coliform was not tested. ◆ Total BOD < 30 mg/L, Monthly Basis: For all filter test conditions in which BOD was sampled and analyzed, values were less than 20 mg/L. Influent to Fuzzy Filter was secondary effluent, which meets this requirement prior to filtration. ◆ TSS < 30 mg/L, Monthly Basis: See discussion on TSS this table. ◆ Average Turbidity < 2 NTU, monthly basis and less than 5 NTU at all times: See turbidity discussion this table. ◆ Dissolved Oxygen > 0 mg/L: Dissolved oxygen concentrations were not determined during testing.

Performance Goal	Fuzzy Filter Performance
♦ Filter Run Times Greater than 24 hours	<ul style="list-style-type: none"> ♦ Filter run times were dependent on operational conditions and influent loading conditions. ♦ Filter run times were less than 24 hours at hydraulic loading rates greater than 10 gpm/ft²
♦ Wash Cycle Waste < 8% of Treated Flow	<ul style="list-style-type: none"> ♦ Filter run times were dependent on operational conditions and influent loading conditions. ♦ Filter run times above 5 hours were required to meet this criteria at loading rate of 10 gpm/ft². Filter run times were greater than 5 hours under a majority of the operational conditions tested, even at influent rates higher than 10 gpm/ft². ♦ Under optimum conditions (20% compression, 30 gpm/ft²) backwash criteria was met under normal influent loading conditions.
♦ Less than 2% Long-Term Increase in Clean Bed Headloss.	<ul style="list-style-type: none"> ♦ Extended testing periods were not of sufficient length to evaluate long-term fouling of the media. Periodic, intensive cleaning of the Fuzzy Filter was successful in returning the media bed to original conditions.

The Fuzzy Filter appears to be acceptable in the treatment of secondary effluent with no chemicals under the conditions tested. Two different testing phases were carried out for treatment of secondary effluent with no chemical addition: operational condition testing and extended testing. The Fuzzy Filter was tested at conditions ranging from 10 gpm/ft² to 40 gpm/ft² (40 gpm to 160 gpm loading rate) and compression rates of 10 to 30%. Based on the results of the testing performed in this study, the following observations can be made:

- The effluent quality achieved by the Fuzzy Filter was dependent on the influent characteristics.
- Secondary effluent (Fuzzy Filter influent) characteristics were dependent on operating conditions at the West Point plant. During high flows, process instability, and bypass events, turbidity in the influent increased significantly.
- During operation of the Fuzzy Filter when the automated wash cycle pressure set point was set at 1.75 psi above the clean bed filter influent pressure, average effluent turbidities of less than 2 NTU were observed when the average influent turbidity was below 3 NTU. Breakthrough of turbidity (i.e., values above 2 NTU) was observed toward the end of filter runs under these conditions.
- Filter run times observed varied depending on influent loading conditions and the operating conditions (i.e. bed compression, hydraulic loading rate, and wash cycle pressure set point) used with the filter.

- The reduction in wash cycle set point reduced the average effluent turbidity observed, but decreased filter run times. In a full-scale facility, effluent turbidity monitoring should be used as an additional control parameter to initiate a wash cycle when a set point effluent turbidity is reached.
- Extended testing indicated that average effluent turbidities of 2 NTU were achieved at average influent turbidities of up to 5.3 NTU when the Fuzzy Filter was operated at 20% compression, 30 gpm/ft² loading rate, and a wash cycle pressure set point of 4 psi. An effluent turbidity of less than 2 NTU was achieved 90% of the time when the average influent turbidity was 4.4 NTU and the maximum turbidity was 10 NTU.
- Although the requirements for less than 8% water wasted was achieved under optimum conditions, the filter run times ranged from 2 to 10 hours. At the shorter filter run times, full-scale feasibility is questionable, particularly under conditions of high loading. Depending on influent conditions, the filter run times can be increased by decreasing influent flow rate or increasing the wash cycle pressure set point.

The hydraulic loading rates feasible for the Fuzzy Filter in this pilot study are significantly higher than for conventional filtration—approximately six to eight times that of conventional filtration. Based on this study, a disadvantage of the Fuzzy Filter is the need for stable influent conditions to consistently achieve acceptable effluent quality. Operational optimization (e.g., control based on effluent turbidity) can overcome this limitation.

The previous work of Caliskaner *et al.* (1999) found that the Fuzzy Filter, when operated at 30% compression and at loading rates between 10 and 30 gpm/ft², could achieve effluent turbidities of less than 2 NTU for influent turbidity values of up to 8 NTU. The authors also observed a general improvement in performance of the Fuzzy Filter when the compression was increased from 15 to 30% compression. The results of the current pilot testing suggest that slightly lower influent turbidities are permissible on a regular basis if an effluent turbidity of 2 NTU is desired. No significant improvement in the effluent turbidity at equivalent turbidity loading rates was observed in this study when the bed compression was increased from 20 to 30%. Differences in permissible influent turbidity between this study and those previously performed may be due to differences in the nature of the solids particles that were present in the Fuzzy Filter influent.

Comparison of Pilot Results to West Point WWTP Filters

The performance of the Fuzzy Filter during the second extended testing period (March 15, 2002 to March 18, 2002) was compared to the performance of the existing West Point WWTP conventional filters relative to turbidity removal, effluent quality, and wash water waste percentages. The West Point WWTP has Dynasand granular media filters that treat a portion of the plant's secondary effluent for production of in-plant reuse water. Prior to the filters, the secondary effluent is chlorinated and screened through a fine screen. The influent to the filters

was the same influent that was fed to the Fuzzy Filter during the pilot testing. PACI is used at the plant filters as a filtration aid.

A comparison of the performance of the West Point WWTP conventional filters and Fuzzy Filter performance during the second extended testing period is shown in Table 25.

Table 25. Comparison of Fuzzy Filter Performance During Second Extended Testing Period to Existing West Point WWTP Filters.

Operation / Performance Parameter	Units	West Point Filters			Fuzzy Filter Second Extended Testing Period (3/15/02 to 3/18/02) Average ^b
		January 2001 through March 2002		March 2002	
		Range	Average	Average	
Secondary Effluent (feed) Turbidity	ntu	2.06 – 7.18	3.88	3.90	4.4
Hydraulic Loading Rate	gpm/ft ²	4.09 – 4.96	4.65	4.84	30
Filter Effluent Turbidity	ntu	0.22 - 1.79	.85	0.37	1.1
Turbidity Removal	%	55 - 91	78	90	72
Wash Cycle Waste	%	4 - 19	10	19	7.5

NOTES:

West Point WWTP filters are Dynasand filters.

PACI is used for filtration aid. During period of operation considered, PACI dosages ranged from 23 to 40 mg/L and averaged 26 mg/L.

Fuzzy Filter data presented is from second extended testing period (March 15, 2002 to March 18, 2002)

Fuzzy Filter effluent turbidity during the second extended testing period was higher than effluent from the West Point plant filters during March 2002, but was only slightly higher than the average effluent turbidity for the existing filters for the data period considered. Similarly, turbidity removal efficiency of the existing filters was higher during March 2002 (90%) relative to Fuzzy Filter performance (72%). When Fuzzy Filter performance is compared to average removals over the entire data period, removal efficiency is only slightly less than for the existing filters. Wash cycle waste percentages for the fuzzy filter were less than the existing filters during both periods.

The results presented above suggest that the Fuzzy Filter performed comparably to the existing filters at hydraulic loading rates from 6 to 7.5 times existing filter loading rates. Although average effluent turbidities were slightly higher and removal efficiency was slightly less than observed in the existing filters when the entire data period is considered, the average effluent turbidity for the Fuzzy Filter was below the Washington State Class A limit. In addition, no chemical was added during the Fuzzy Filter test period considered. Based on the results of pilot testing, addition of coagulant would likely increase removal efficiency and result in lower average effluent turbidities.

Tertiary Treatment With Chemical Addition

The performance of the Fuzzy Filter in the treatment of secondary effluent with chemical addition relative to the performance objectives established for the pilot study is shown in Table 26.

Based on the results of the pilot testing, the following conclusions can be made:

- ❑ PACl was a more effective chemical coagulant than alum under the conditions of the testing.
- ❑ Coagulant addition prior to the Fuzzy Filter decreases the average effluent turbidity at similar turbidity loadings relative to no chemical addition.
- ❑ Adequate mixing and reaction time to ensure effective floc formation must be provided upstream of the Fuzzy Filter to achieve optimum TSS and phosphorus removal and chemical usage.
- ❑ PACl dosage rates of 70 mg/L were required to achieve phosphorus removal to levels established in the performance objectives under the conditions tested. However, coagulant addition at this rate resulted in run times less than two hours, making implementation and reliable performance questionable.
- ❑ The reduction of the wash cycle pressure set point reduced the average effluent turbidity observed, but also decreased filter run times. In a full-scale facility, effluent turbidity should be used as an additional control parameter to initiate a wash cycle when an effluent turbidity set point is reached.
- ❑ The addition of small amounts of coagulant can improve the reliability of the effluent quality with minor reductions in filter run time.

Few studies have been published on the performance of the Fuzzy Filter with chemical treatment. Burchett *et al.* (2000) found that the addition of chemicals improved Fuzzy Filter performance when the characteristics of the influent changed, and that unacceptable effluent quality resulted when no chemicals were added. No information was available from the study on the chemical dosages used for improvement of filter performance.

Table 26. Comparison of Performance Goals and Results for Tertiary Treatment with Chemical Addition

Performance Goal	Fuzzy Filter Performance
◆ Effluent TSS < 5 mg/L 90 th percentile	<ul style="list-style-type: none"> ◆ TSS removal efficiency and effluent concentrations varied with influent TSS concentrations. ◆ Extended testing was not performed.
◆ Effluent Turbidity < 2 NTU, 90 th percentile	<ul style="list-style-type: none"> ◆ Extended testing was not performed. ◆ Average effluent turbidity was less than 2 NTU for all operational conditions tested when average influent turbidity was less than 5.5 NTU.
◆ Effluent t-P < 0.5 mg/L 90 th percentile	<ul style="list-style-type: none"> ◆ Chemical coagulant dosages of 70 mg/L PACl were required to achieve an effluent t-P < 0.5 mg/L. ◆ No extended testing was performed on tertiary treatment with chemical application.
◆ Compliance with Washington State Class A Standards	<ul style="list-style-type: none"> ◆ Process Requirements – With chemical addition, the Fuzzy Filter meets the process requirements for Washington State Class A standards. Oxidation and disinfection were provided upstream of the Fuzzy Filter during this study. ◆ Disinfection Requirements – Removal of total Coliform was not tested. ◆ Total BOD < 30 mg/L, Monthly Basis – For all filter test conditions in which BOD was sampled and analyzed, values were less than 20 mg/L. Influent to Fuzzy Filter was secondary effluent, which meets this requirement before further treatment. ◆ TSS < 30 mg/L, Monthly Basis – See discussion on TSS this table. No values exceeded 30 mg/L. ◆ Average Turbidity < 2 NTU, monthly basis and less than 5 NTU at all times – See Turbidity Discussion ◆ Dissolved Oxygen > 0 mg/L – Dissolved oxygen concentrations were not tested during the study.
◆ Filter Run Times Greater than 24 hours	<ul style="list-style-type: none"> ◆ Filter run times were dependent on operational conditions, influent loading, and chemical feed applied. ◆ Performance goal not met in any of conditions tested.
◆ Wash Cycle Waste < 8% of Treated Flow	<ul style="list-style-type: none"> ◆ Filter run times were dependent on operational conditions, influent loading, and chemical feed applied. ◆ Filter run times above 5 hours at hydraulic loading rates of 10 gpm/ft² are required to meet this criteria and can be met with many of the test conditions. ◆ Minimum filter run times not met at 70 mg/L PACl dosage required to remove phosphorus.
◆ Less than 2% Long-Term Increase in Clean Bed Headloss.	<ul style="list-style-type: none"> ◆ No extended testing was performed. Periodic, intensive cleaning of the Fuzzy Filter was successful in returning the media bed to original conditions.

The performance of the Fuzzy Filter with chemical coagulant addition can be considered from two perspectives relative to acceptable performance:

- Performance relative to achieving low effluent phosphorus concentrations (i.e., <0.5 mg/L t-P).
- The improvement of performance relative to turbidity removal by the addition of small amounts of coagulant.

Dosage rates of 70 mg/L PACl were required to achieve low effluent phosphorus concentrations. At these dosages, the suspended solids loading to the filters increased and resulted in filter run times of one to two hours. While effluent turbidities were found to be well below 2 NTU, the frequency of backwash significantly increased. The high frequency of backwash makes full-scale implementation of a Fuzzy Filter at these conditions questionable.

The addition of coagulant at low doses (i.e., 15 mg/L) was shown to result in effluent turbidities that were well below 2 NTU for the conditions tested during the pilot testing. This effluent quality was achievable at filter run times that were comparable to those observed with no chemical treatment. In addition, the use of coagulants generally increased the permissible influent turbidity relative to no chemical use for the operational parameters tested. Therefore, a chemical feed system may be warranted in full-scale application, even if phosphorus removal is not required, particularly if influent solids conditions are highly variable. The chemical feed system in this application would serve as a backup to provide chemical feed in situations where improvements in effluent quality are needed, either because of changes in influent concentration or characteristics.

Implementation

Tertiary Treatment With No Chemical Addition

Suggested Design Criteria

Based on the results of the pilot testing performed, the following design criteria would be recommended for full-scale implementation of a Fuzzy Filter system with no chemical feed:

- 30 gpm/ft² hydraulic loading rate with two units off-line (one in backwash, one out of service) at the design influent flow rate.
- Turbidity loading of less than 130 gpm/ft²-NTU to achieve effluent turbidity of 2 NTU 90% of the time.
- Zero to 30% compression capability – 20% bed compression as a default.
- 35-inch nominal media depth (at 0% compression).
- Minimum of four filter units.
- Average influent turbidity concentration of less than 4.4 NTU (and maximum of 10 NTU) required to achieve 2 NTU, 90th percentile.

Prior to full-scale implementation, the following issues should be considered for a full-scale Fuzzy Filter process:

- **Desired Effluent Quality:** The above design criteria are based on meeting the objectives for this pilot study. If the effluent quality desired is significantly different, the design criteria should be re-evaluated.
- **Influent Characteristics:** The effluent quality that can be expected from the Fuzzy Filter is dependent on the influent characteristics. If the influent characteristics, particularly turbidity, are significantly different or highly variable, then the design criteria for the Fuzzy Filter unit process should be re-evaluated and adjusted accordingly. An additional consideration relative to influent characteristics is the particle size distribution of the influent. If the upstream processes to the Fuzzy Filter are different than those used in the West Point plant, adjustment of operational parameters on the unit may be required.
- **Variation in Influent Characteristics:** During periods of high flow to the West Point plant, the turbidity concentration in the influent of the Fuzzy Filter often increased dramatically. The increase in influent turbidity was often accompanied by an increase in effluent turbidity from the Fuzzy Filter and shortened run times between backwashes. The design criteria above assume that the influent characteristics will be relatively consistent over time. If more significant variations in flow and influent characteristics are expected, the design criteria should be reconsidered. Under conditions of higher influent turbidities, the addition of small amounts of coagulants may improve performance relative to effluent quality.
- **Full-Scale Implementation Cost Relative to Conventional Filtration:** Prior to full-scale application, a full evaluation of the capital and operating costs of the Fuzzy Filter should be performed. Estimated costs for full-scale implementation were not considered in this study. The evaluation should include consideration of effluent treatment goals, capital costs, operational scenarios, operating costs, and life cycle maintenance costs.
- **Filter Run Time:** Filter run times were found to range from two to ten hours for the operational conditions recommended for full-scale design. If frequent and lengthy periods of increased influent turbidity are expected, consideration should be given to lowering the influent hydraulic loading rates for full-scale design.

Design Features

Control and Monitoring

Standard full-scale installations of Fuzzy Filters include control panels and associated functionality that is similar to those used during this pilot testing, and that is recommended. The following additional control and monitoring capabilities are recommended:

- **Continuous effluent turbidimeter:** A turbidimeter capable of continuous measurement of turbidity at low levels should be installed on each Fuzzy Filter. Such an effluent

turbidimeter would satisfy the monitoring requirements for Washington State Class A water reuse standards.

- **Effluent Turbidity as Control Parameter for Wash Cycle:** In addition to using filter influent pressure to trigger a wash cycle, it is recommended that provisions be included for automatic washing of filters when effluent turbidity increases to a predetermined set point level. This additional control measure will provide reliability to ensure consistent compliance with effluent turbidity requirements.
- **Influent Flow Control:** An inline control valve was used during pilot testing to regulate the flow rate to the Fuzzy Filter. Flow to the Fuzzy Filter should be automatically regulated to maintain consistent influent flow rates. Different methods of flow control, including pump VFDs and/or control valves could be used in a full-scale application.

Pretreatment Requirements

There are no pretreatment requirements that are required for full-scale application of the Fuzzy Filter for treatment of secondary effluent. However, as was observed during the pilot testing, the performance of the Fuzzy Filter is dependent on the characteristics of the influent to the Fuzzy Filter. Therefore, attention must be given to the processes upstream of the Fuzzy Filter to ensure that the characteristics of the influent feed are relatively consistent and that they are within the limits presented in the conclusions section to produce an acceptable effluent quality.

Residual Treatment

The primary residual associated with the Fuzzy Filter is wash cycle water generated during cleaning of the media bed. Similar to conventional filtration, the wash cycle water can be expected be high in TSS and BOD. Therefore, it is recommended that, in a full-scale application, the wash cycle water be returned to the head of the secondary treatment system. This is the common method of residual treatment for conventional filtration.

Tertiary Treatment with Chemical Addition

Suggested Design Criteria

Based on the testing conducted on the Fuzzy Filter treating secondary effluent with chemical addition, a PACl dose of 70 mg/L was required to achieve effluent total phosphorus levels below 0.5 mg/L. At these dosages and the hydraulic loading rates tested (25 to 30 gpm/ft²; 100 to 120 gpm), filter run times were very short, ranging from one to two hours in duration. At these filter run times, a full-scale application of Fuzzy Filters would not be recommended. Because of the short run times, the probability of multiple filters being in the backwash cycle simultaneously is very high. Therefore, an excessive number of filters would be required. Because no testing was performed at low influent flow rates to verify performance and run duration, no design criteria are provided for chemical addition for phosphorus removal.

If chemical feed is desired for preventing excursions in effluent turbidity, it is recommended that the facility be designed with criteria similar to those with tertiary treatment with no chemical addition. Chemical feed facilities in this case should be designed based on providing

a total capacity of coagulant addition at a dosage of approximately 30 mg/L. The facilities would serve in a standby capacity mode. Therefore, chemical storage facilities would not have to be designed for standard 30-day holding capacities. Rather, a storage capacity of approximately one week at design flow rates would be recommended.

Design Features

Control and Monitoring

The recommended control features in a full-scale application of the Fuzzy Filter with chemical treatment are the same as those recommended for systems without chemical addition. The chemical feed facilities should be designed to include automated feed trim based on variations in flow. In addition, normal capabilities for manual and automatic control should be provided for the chemical feed system.

Pretreatment Requirements

Requirements for pretreatment in an application using chemical feed are the same as for applications with no chemical addition.

Residual Treatment

Requirements for pretreatment in an application using chemical feed are the same as for applications with no chemical addition.

Issues Not Resolved by the Pilot Test Program

Tertiary Treatment With and Without Chemical Addition

Due to schedule limitations and the intended scope of the Fuzzy Filter testing, a few issues were not considered fully during the pilot testing:

- **Backwash duration to regain full use of filter bed:** Limited attention during the pilot testing was given to the optimization of backwash procedures. A backwash duration of 20 minutes was used throughout the test, based on recommendations from the manufacturer. Minor modifications were made at the beginning of tertiary testing to assure that all washed solids were removed from the filter prior to the beginning of another filter run. However, because of the high hydraulic loading rates possible with the Fuzzy Filter, the impact of the backwash duration is much smaller than with conventional filtration.
- **Potential for long-term accumulation of solids in media:** Long-term accumulation potential for solids in the media bed could not be fully investigated in the duration of the pilot study. No appreciable buildup of filter influent pressure was observed throughout the filter runs. In addition, the manufacturer's recommended quarterly cleaning procedures (hypochlorite washing) were used twice during the pilot testing (between primary and tertiary testing with no chemical addition) and between tertiary with and without chemical addition, to ensure that no buildup of material occurred in the media bed. Prior to full-scale implementation, existing installations should be contacted to

determine if long-term fouling is an issue at those facilities. Based on the results and efficiency of cleaning the Fuzzy Filter media when using primary influent, it appears that the media can be cleaned very effectively and returned to its original state.

However, fats, oils, and greases (FOG), common constituents in raw wastewater, were not encountered during primary influent testing due to limited influent quantities and/or effective treatment upstream of the filter. Therefore, care should be taken in the design of any Fuzzy Filter application to reduce the potential for FOG related clogging of the filter.

- **Media Bed Depth:** The manufacturer-supplied media depth was used during the pilot study, and no attempts were made to quantify the effects of using additional or less media. Increases in run time may be achievable with increased bed depth. However, the increase in bed depth may result in an undesirable increase in filter bed headloss.
- **Performance with Chemical Addition over Extended Testing Period:** Although a significant amount of testing was performed during tertiary treatment with chemical addition, no extended testing was performed with chemical addition with the specific purpose of removing phosphorus. Therefore, long-term performance was not evaluated.
- **Effectiveness of Floc Formation Upstream of the Fuzzy Filter:** The ability of the Fuzzy Filter to remove TSS and phosphorus and the required chemical dosages are strongly related to the degree of floc formation upstream of the filter. The degree of floc formation achieved depends heavily on the mixing provided at the point of chemical injection and reaction time prior to the filter. In this pilot study, no mixing was provided at the point of chemical injection, and a limited reaction time was available (i.e. two minutes total). Although some improvement in removal was seen with the use of PACl relative to alum, the completeness of flocculation prior to the filter was not investigated for either chemical. Therefore, the coagulant dose was not truly optimized for the operation of the Fuzzy Filter.

References

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Burchett, M.E., S. C. Rosa, A. Carolan, and G. Tchobanoglous. (2000). Using the “Fuzzy” Filter to Produce Title 22 Recycled Water. *Paper presented at California Water Reuse Conference, Napa, CA.* .

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Appendix A - Test Plan and Filter Cleaning Procedure

Appendix B - Primary Treatment Graphs

Appendix C - Tertiary Treatment With No Chemical Addition Graphs

Appendix D - Tertiary Treatment With Chemical Addition Graphs

Appendix E - Laboratory Data

Appendix F - Operator Notes

Appendix G - Pilot Unit Photos

Description of Contents - Appendix A

Appendix A contains the original testing and sampling plan developed prior to the pilot testing of the Fuzzy Filter. The testing and sampling plan contains a summary of the original testing plan, schedule, and the manufacturer recommended cleaning procedures for the Fuzzy Filter. The original testing and sampling plan was modified during the pilot testing to address changes in schedule, operational issues identified, and observations made during testing. The actual testing that took place for each phase is summarized in separate tables for each phase of testing. Actual laboratory samples taken for each test period can be found in Appendix E. Samples taken during each testing period can be cross referenced by the start date of the test (i.e. match date of laboratory results to start date of each test).

A summary of the contents of Appendix A and the associated electronic files for each subsection are shown in Table A.

Table A. Summary of Contents of Appendix A

Appendix Subsection	Contents	Electronic File Name
A-1	Original sampling and testing plan and manufacturer's recommended quarterly cleaning procedure. Original sampling plan and schedule is an attachment to the document (Table 4).	A1 – Fuzzy Filter Test Plan.doc (written test plan and cleaning procedures) A1 – Table 4 – Original Sampling Plan and Schedule. xls (Table 4 attachment to original testing plan)
A-2	Final summary of testing conducted for Fuzzy Filter in treatment of primary influent.	Appendix A – A2 through A4.xls (Worksheet within file – A2 - Final Primary)
A-3	Final summary of tests conducted for testing of Fuzzy Filter in treatment of secondary effluent with no chemical addition..	Appendix A – A2 through A4.xls (Worksheet within file – A3 - Final Tert. No Chem)
A-4	Final summary of tests conducted for testing of Fuzzy Filter in treatment of secondary effluent with no chemical addition..	Appendix A – A2 through A4.xls (Worksheet within file – A4 - Final Tert. No Chem)

Description of Contents - Appendix B

Appendix B contains graphs generated from data gathered during pilot testing of the Fuzzy Filter in treatment of screened and de-gritted primary influent. The first 13 pages of graphs contain real time data gathered during normal testing of the Fuzzy Filter. The last two pages (with title, “Short-Term Fuzzy Filter Testing to Investigate Short-Circuiting”) contain graphs of short term testing that was performed toward the end of the primary influent testing to investigate short circuiting of influent flow along the sidewalls of the Fuzzy Filter. The graphs shown on the first thirteen pages of the Appendix are shown with influent flow rate (gpm) rather than hydraulic loading rate (gpm/ft²). The hydraulic loading rate can be determined from the influent flow rate by dividing by four (the Fuzzy Filter had an area of 4 ft²). All graphs can be cross-referenced to laboratory results (Appendix E) and the discussion in the main body of the report based on start date and testing conditions. Bed pressure as shown on all the graphs represents the filter influent pressure. The filter influent pressure was measured at the influent to the fuzzy filter and includes static water between the influent and effluent (approximately 6 feet) and the headloss through the media at a given flow.

Description of Contents - Appendix C

Appendix C contains graphs generated from data gathered during pilot testing of the Fuzzy Filter in treatment of secondary effluent from the West Point WWTP. Each graph contains a test condition number that can be cross-referenced to Table 12 of the main body of the report. Similarly, results of laboratory analysis in Appendix E can be cross-referenced by the start date of the test.

The graphs are shown in terms of influent flow rate (gpm) rather than hydraulic loading rate (gpm/ft²). The hydraulic loading rate can be determined from the influent flow rate by dividing by four (the Fuzzy Filter had an area of 4 ft²). Bed pressure as shown on all the graphs represents the filter influent pressure. The filter influent pressure was measured at the influent to the fuzzy filter and includes static water between the influent and effluent (approximately 6 feet) and the headloss through the media at a given flow. The influent turbidity shown on the graphs was determined from the West Point WWTP secondary clarifier effluent. Prior to being fed to the fuzzy filter (and after turbidity measurement), the secondary clarifier effluent was chlorinated and screened through a fine screen with 1/16" openings.

West Point plant flow is also shown on the graphs. During periods of high rainfall, flows above 300 MGD receive primary treatment and are then bypassed around the secondary treatment system. During periods when the plant flow was above 300 MGD, the influent turbidity shown on the graphs does not include contributions from the bypassed primary effluent. In the final report data analysis, this data was excluded because the exact influent turbidity to the Fuzzy Filter was not known. Further discussion is included in the main body of the report.

Description of Contents - Appendix D

Appendix D contains graphs generated from data gathered during pilot testing of the Fuzzy Filter in treatment of secondary effluent from the West Point WWTP with chemical coagulant addition. Each graph contains a test condition number that can be cross-referenced to Table 13 of the main body of the report. Similarly, results of laboratory analysis in Appendix E can be cross-referenced by the start date of the test.

The graphs are shown in terms of influent flow rate (gpm) rather than hydraulic loading rate (gpm/ft²). The hydraulic loading rate can be determined from the influent flow rate by dividing by four (the Fuzzy Filter had an area of 4 ft²). Bed pressure as shown on all the graphs represents the filter influent pressure. The filter influent pressure was measured at the influent to the fuzzy filter and includes static water between the influent and effluent (approximately 6 feet) and the headloss through the media at a given flow. The influent turbidity shown on the graphs was determined from the West Point WWTP secondary clarifier effluent. Prior to being fed to the fuzzy filter (and after turbidity measurement), the secondary clarifier effluent was chlorinated and screened through a fine screen with 1/16" openings. The turbidity shown on the graphs is prior to chemical coagulant addition.

West Point plant flow is also shown on the graphs. During periods of high rainfall, flows above 300 MGD receive primary treatment and are then bypassed around the secondary treatment system. During periods when the plant flow was above 300 MGD, the influent turbidity shown on the graphs does not include contributions from the bypassed primary effluent. In the final report data analysis, this data was excluded because the exact influent turbidity to the Fuzzy Filter was not known. Further discussion is included in the main body of the report.

This appendix also contains data taken to investigate spikes in effluent turbidity that were observed during the pilot testing. Operations staff took samples from the Fuzzy Filter wash cycle waste water during the last stage of the wash cycle (purge stage) in which the filter media is compressed and influent is fed to the media. During the purge stage, the water is wasted. The turbidity of the wash water during the purge cycle was very low, suggesting that the spike in turbidity seen just after the wash cycle is completed is due to accumulated solids in the filter effluent pipe between the filter and the isolation valve.

A summary of the contents of Appendix D and associated file locations are shown in Table D.

Appendix Subsection	Contents	Electronic File Name
D-1	Graphs for test conditions during testing of Fuzzy Filter in treatment of secondary effluent with chemical addition.	D1 – Tertiary Treatment with Chemical Addition Graphs.doc
D-2	Data gathered during testing to investigate spikes in turbidity immediately after a wash cycle.	D2-Data on High Turbidity.xls

Description of Contents - Appendix E

Appendix E contains the results of laboratory analysis performed on influent and effluent samples for Fuzzy Filter pilot testing. All of the analysis were performed by the West Point WWTP Laboratory according to Standard Methods. Laboratory results for each test performed on the Fuzzy Filter can be cross-referenced to the specific test condition based on the start date of each test.

Description of Contents - Appendix F

Appendix F contains notes recorded by operations staff during the Fuzzy Filter pilot testing.

Description of Contents - Appendix G

Appendix G contains photos of the Fuzzy Filter during the pilot testing. Each photo includes a caption and text boxes to point out key pieces of equipment.

Fuzzy Filter Test Plan

Background and Purpose

The Fuzzy Filter (FF), manufactured by Schreiber is one of eight unit processes to be tested during the King County Water Reuse Demonstration Project. The FF unit, originally supplied and intended for operation and testing in a primary treatment application, is on site and will be ready for operation and testing during the week of September 17, 2001. Pilot unit testing is expected to begin on October 5, 2001. A total testing period of five months is anticipated for the FF. During the first two months, the filter will be tested in a primary application. During the last three months, the filter will be tested in a tertiary application.

The FF operates under the same physical-chemical removal mechanisms as a conventional filter. The FF, however, uses compressible media, consisting of synthetic fiber porous material. The properties of the media, including porosity and effective pore size can be varied by adjusting the amount of compression applied to the media bed. The media is also highly porous, making it possible to store more particulate matter removed from the flow inside the media bed. Previous studies have shown that the fuzzy filter can perform equivalent to conventional filtration technologies while maintain hydraulic loading rates 5 to 12 times higher than other filters.

The purpose of this document is to outline the proposed testing procedures for the FF pilot unit that is on site. This document is intended to serve as a guide for County staff to begin testing the FF. The plan will be updated as necessary during the testing based on data collected and reviewed by the Project Team.

Pilot Testing Objectives

The objective of piloting the FF unit process is to evaluate performance under both primary and tertiary treatment applications. In primary treatment, piloting is intended to assess the effectiveness of the unit in removing BOD and suspended solids (SS). Enhanced removal of BOD, SS, and phosphorous removal will also be evaluated using chemical coagulants. Filter operating characteristics, such as filter run time, hydraulic loading rate (HLR), and bed compression will also be evaluated.

In tertiary treatment, piloting is intended to assess whether the unit process can be used in a tertiary application to meet Class A reuse requirements and if the filter is effective in removal of phosphorous to concentrations of less than 0.5 mg/l. Filter operating characteristics required to meet these performance goals will be included in the evaluation.

The detailed objectives of each phase of testing, as well as performance goals, are included in Table 1.

Table 1. Objectives and Performance Goals of Fuzzy Filter Testing

Key Performance Questions	Performance Goals
Primary Application without Chemical Addition	
<ul style="list-style-type: none"> ◆ Ability of system to operate when receiving raw wastewater. ◆ Tendency of filter to plug. ◆ Ability to remove solids – effluent quality at various periods during filter run. ◆ Potential for long term accumulation of solids in media (fouling). ◆ Length of filter runs and ratio of backwash volume to treated volume. ◆ Backwash sequencing to regain full use of bed. ◆ Upper limit of solids loading 	<ul style="list-style-type: none"> ◆ Backwash intervals exceeding 24 hours. ◆ >80% TSS removal ◆ Backwash flow <8% of treated flow. ◆ Zero long-term buildup of clean bed headloss.
Primary Application with Chemical Addition	
<ul style="list-style-type: none"> ◆ Ability to remove phosphorus ◆ Improvement in TSS and BOD removal when alum is used. ◆ Impact of alum addition on run time, fouling potential, backwash requirements ◆ Impact of alum addition on solids loading capacity. ◆ Optimal alum dosage 	<ul style="list-style-type: none"> ◆ Backwash interval exceeding 12 hours. ◆ >80% TSS removal ◆ >80% TP removal with alum. ◆ Backwash flow <8% of treated flow. ◆ Zero long-term buildup of clean bed headloss.
Tertiary Application with and without chemical addition	
<ul style="list-style-type: none"> ◆ Tendency of filter to plug. ◆ Ability to remove solids – effluent quality at various periods during filter run. ◆ Potential for long-term accumulation of solids in media (fouling). ◆ Length of filter runs and ratio of backwash volume to treated volume. ◆ Backwash sequencing to regain full use of bed. ◆ Upper limit of solids loading ◆ Impact of coagulant addition on run time, fouling potential, and backwash requirements. 	<ul style="list-style-type: none"> ◆ Effluent TSS < 5 mg/l, 90th percentile. ◆ Effluent turbidity < 2 mg/l, 90th percentile ◆ Effluent TP concentrations < 0.5 mg/l, 90th percentile. ◆ Compliance with Class A reclaimed water requirements. ◆ Cleaning frequency exceeding 24 hours. ◆ Backwash flow <8% of treated flow. ◆ Less than 2% long increase in clean bed headloss per year.

Performance Goals Relative to Regulatory Requirements and Full Scale Design

The pilot testing proposed herein is intended to evaluate the applicability of the fuzzy filter for use in meeting Class A reuse requirements and performance relative to nutrient removal in combination with other unit processes. The performance goals originally established for the fuzzy filter were established based on the rated capacity of the wastewater plant and would likely be used as the basis for full scale design of the filters. The application of the fuzzy filter in a scalping reclamation plant does not impart variation of flow (i.e. maximum month flows, peak day flows, and diurnal flow and loading variation) as is typical in most plants. However, it is

important to consider the performance of the fuzzy filter under increased loading conditions like those that would be expected when single filters are backwashed. For instance, when one filter in a full-scale application of four individual units is backwashed, an increase in flow of approximately 33% would be experienced by the other three filters if the flow to the filters is held constant. Under this type of situation, the filters must still be able to prevent short term excursions in effluent requirements that would jeopardize permit compliance

During the testing of the fuzzy filter, chosen operational parameters will be tested over extended periods. During this testing, the pilot unit will be subjected to a 33% increase in flow to simulate backwash of one filter. While large excursions in effluent TSS, turbidity, BOD, etc. would not be expected, this condition will be tested to evaluate conditions more representative of full scale application. Testing procedures to evaluate extended operation will be discussed in the testing section of this plan.

Pilot Unit Operation

The Fuzzy Filter consists of a media bed of fibrous type spheres that are compacted by a top retainer plate. The media is supported off the filter floor by a bottom retainer plate that is fixed in position. Flow through the media is upward and the filter operates on a constant discharge, variable head principle. As filter run time increases, the pressure at the inlet of the filter increases. The pilot unit supplied contains a media bed that is 4 ft² in area and approximately 34" thick at zero compression (defined as condition when top retainer plate just touches the top of the filter bed under no inlet flow conditions). With the exception of the influent feed pump, the pilot unit to be tested has been supplied with all accessories and equipment required for automated operation of the filter, including backwash. The local control panel supplied with the unit has a touch screen menu system that will allow adjustment of operating parameters. Both automatic and manual operation are possible with the unit; it is recommended, however, that during testing the unit be left in automatic mode. The control system provided by the manufacturer includes alarm conditions and automatic shutdown of the filter to prevent unit damage and to allow unattended operation.

A control summary provided by Schreiber for the pilot test unit is attached to this document. A summary of key operating parameters and method of control is included in Table 2.

Table 2. Summary of Key Operating Parameters, Method of Control and Suggested Operating Ranges			
Parameter	Method of Control	Suggested Operating Range ^a	
		Tertiary	Primary
Filter Operation – Filter Period			
Hydraulic Loading Rate (influent feed rate)	<ul style="list-style-type: none">◆ Current system requires manual adjustment of BV10 and DV9; changes are in progress to allow automatic control of influent flowrate◆ After modifications, feed rate to be input on master system PLC. Valve on inlet side of filter to be modulated to	15-30 gpm/ft ² (60-120gpm) 40 gpm/ft ² - peak	5-20 gpm/ft ² (20-80 gpm)

	<p>maintain setpoint flow. (Changes expected to be completed on October 15th)</p> <ul style="list-style-type: none"> ◆ Feed rate measured at flowmeter (FE/FIT-3) on influent line to filter. 		
Media Bed Compression	<ul style="list-style-type: none"> ◆ Bed compression is measured in % and is the operating bed depth divided by the 0% bed depth. ◆ Bed compression controlled by top retainer plate. Top retainer plate moved into position at beginning of filter run by top retainer plate motor. ◆ In automatic, bed compression automatically set to input level by pilot unit PLC. ◆ Set bed compression (%) in media compression set point screen of Fuzzy Filter PLC. ◆ Bed compression calibrated to 0% prior to test. Between testing phases (i.e. between Phases 1-4, bed compression measurement should be recalibrated. 	10-35%	0-25%
Wash Cycle Pressure Setpoint	<ul style="list-style-type: none"> ◆ When inlet pressure reaches wash cycle setpoint, filter will automatically initiate a wash cycle. ◆ Pressure setpoint input in WASH PRESSURE SETPOINT screen in PLC. ◆ NOTE: For each bed compression and hydraulic loading rate, wash cycle setpoint must be entered into FF PLC. ◆ Setpoint determined by clean filter headloss (at beginning of filtration) and adding 1.75 psi. 	48" above clean bed headloss (1.75 psi above inlet pressure at start of filtration mode)	48" above clean bed headloss (1.75 psi above inlet pressure at start of filtration mode)
Filter Run Time	<ul style="list-style-type: none"> ◆ Controlled based on either time or influent pressure. ◆ Time interval set on filter status screen in wash time dialog box. ◆ Pressure setpoint input in WASH PRESSURE SETPOINT screen in PLC. ◆ Inlet pressure to be primary mode of backwash for filter with 24 hour maximum run time. ◆ Setpoint on TIME to BACKWASH to be set at 24 hours during testing. 	Time depends on hydraulic loading rate, influent feed characteristics, and bed compression.	Time depends on hydraulic loading rate, influent feed characteristics, and bed compression.
Filter Wash Cycle			
Wash Cycle Flowrate	<ul style="list-style-type: none"> ◆ Feed rate controlled by external controls (see Hydraulic Loading Rate above). ◆ At time of backwash signal sent from FF to external PLC to initiate wash cycle feed rate. ◆ Feed rate controlled by control valve modulated to maintain setpoint flow. 	10 gpm/ft ²	10 gpm/ft ²

	<ul style="list-style-type: none"> ◆ Feed rate measured at flowmeter on influent line to filter 		
Air scour flowrate	<ul style="list-style-type: none"> ◆ Air scour flowrate fixed; it is not variable on unit. ◆ Air supplied to one of two headers beneath bottom retainer plate. ◆ Sequence of air scour controlled by wash cycle phases (see below). 	15 scfm/ft ²	15 scfm/ft ²
Wash Cycle Time	<ul style="list-style-type: none"> ◆ Wash cycle separated into a total of six phases of washwater and air scour. ◆ Time of each phase variable from 60 seconds to 600 seconds; manufacturer recommends they change together. ◆ Control times on SEQUENCE TIMER ADJUSTMENT SCREEN. ◆ Wash to be initiated a minimum of once every 24 hours. ◆ NOTE: wash cycle duration to be held constant at a total of 20 minutes during the pilot testing. 	10-25 minutes	20-40 minutes
Purge Time	<ul style="list-style-type: none"> ◆ Controls “filter to waste” duration after wash cycle. ◆ Variable from 200 to 600 seconds. ◆ Controlled from SEQUENCE TIMER ADJUSTMENT SCREEN. ◆ NOTE: purge time should be held constant during duration of testing. 	5-10	5-10

Pilot Test Plan

Overview

The proposed testing plan for the FF includes a total of five distinct phases:

- Phase 1 – Primary Treatment without chemical addition
- Phase 2 – Primary Treatment with chemical addition
- Phase 3 – Tertiary Treatment with chemical addition (Class A reuse and nutrient removal evaluation).
- Phase 4 – Tertiary treatment without chemical addition.

Each phase of the pilot testing proposed above is intended to assess the performance questions outlined in Table 1 and evaluate the unit’s ability to meet the performance goals established for the pilot testing project.

Overall Pilot System Considerations

The original pilot test plan for the FF has been modified from the original proposed plan. Changes incorporated into the current test plan include the following:

- ◆ The same FF pilot unit will be used for both primary and tertiary treatment testing.
- ◆ Due to lower than expected capacity of the BAF, influent for the FF during tertiary treatment will be supplied from C3 water from the West Point WWTP.
- ◆ Under the current plan, FF effluent will be discharged to a process drain. If possible, FF effluent can be used as feed to BAF 1 during the primary application testing periods. If it is decided that FF effluent will be fed to BAF 1, the test plan will be changed accordingly.
- ◆ Currently, the influent feed pump for the fuzzy filter will accommodate flowrates of up to 90 gpm. Changes are being made to the pump to allow higher flows of up to 120 gpm (30 gpm/sf at highest bed compression). Therefore, primary testing will first consider conditions involving lower flowrates.
- ◆ Currently, the influent feed pump will require manual adjustment to maintain constant flowrates. Changes are currently being made to provide automatic control of the influent flow rate to maintain constant flows to the filter. Changes are expected to be in place by October 15, 2001.

Test Conditions

General

Testing conditions will be varied during different phases of the testing period. During tertiary testing, West Point WWTP secondary effluent (C3 water) will be used as influent for the FF. In the primary testing, West Point primary influent that has passed through a fine screen will be used for influent to the FF. In general, each testing condition will be run for a period of 24 hours, except in cases of extended period testing.

The wash cycle after each filter run is intended to remove accumulated solids from the filter media. Wash cycles will be held constant according to wash cycle parameters suggested by the manufacturer. More intensive washing is generally recommended quarterly by the manufacturer. A more intensive cleaning should therefore be performed at least once during the testing period. It is recommended that the intensive cleaning procedure take place after the tertiary testing is complete (i.e. between tertiary and primary testing). The cleaning procedure recommended by the manufacturer is attached to this document. More intensive cleaning may be required during interim periods if substantial buildup is noted on the filter media after backwashing or if clean bed headloss has increased substantially.

General Testing Procedures

The fuzzy filter pilot unit supplied for the testing program is equipped with controls which will allow the unit to be operated unattended during most of the time. During initial portions of the testing it will be necessary to manually operate the influent pump and associated control valves

to maintain constant flow to the filter. General test operation for the FF pilot unit will involve the following:

Common Testing Operation

- ◆ The filter will be run under constant flow conditions (and varying inlet pressure) during all testing. Note that during extended period testing influent flowrates will be increased for short periods to simulate full scale backwash conditions.
- ◆ Changes in test conditions should be made at the beginning of each day. Except in the case of extended operational testing (discussed in a later section), test conditions will be changed on a daily basis. Changes in the operational parameters should be made at the beginning of each test day.
- ◆ A wash cycle should be initiated prior to a change in test conditions.
- ◆ Wash cycle pressure setpoints will require adjustment for each test condition (i.e. changing hydraulic loading rate or bed compression). To set the wash cycle pressure setpoint, add 1.75 psi to the initial inlet pressure at the beginning of each test period. Wash cycle setpoint pressures can be modified using the WASH PRESSURE SETPOINT screen in the PLC.
- ◆ During the pilot testing, “intensive cleaning” of the filter media will be required at least one time. It is suggested that this cleaning cycle take place between primary and tertiary testing (see detailed sampling plan). A description of the intensive cleaning procedure is attached to this plan.
- ◆ “Intensive cleaning” of the filter media should be performed whenever the filter media experiences a substantial increase in “residual” material after backwash. Indications of the need for intensive cleaning will include noticeable buildup of material on the media (observed through the unit windows) and a substantial increase in inlet pressure at the beginning of a filtration period (clean bed headloss). A figure showing clean bed headloss for a similar study is attached to this document as a reference. If clean bed headloss is observed to be 20% greater than the values shown in the figure, intensive cleaning should be considered. It is suggested that multiple wash cycles be attempted prior to initiating intensive cleaning.
- ◆ Composite samplers should be reset at the beginning of the filtration period for the new testing conditions.
- ◆ Consistent wash cycle parameters will be used throughout the testing period. Setpoints for wash cycle operation:
 - Wash cycle washwater flowrate – 10 gpm/ft² (40 gpm total)
 - Wash cycle duration – 20 minutes (200 seconds for each of 6 sequences)
 - Purge time – 5 minutes

- Air scour flowrate – 15 cfm/ft² (60 cfm total)
- ◆ Changes in wash cycle parameters should only be considered if noticeable buildup on the media is visually noticed, if starting influent pressures exceed those discussed above. It is suggested that difficulties and observations related to backwashing be discussed by conference call with the manufacturer and Project Team when they arise.

Manual Influent Pump Adjustment Operation (initial periods of testing – until October 15th)

- ◆ Test duration will be 24 hours. Manual adjustment of influent flowrate to the desired test flowrate should be done once per hour (maximum of once every two hours).
- ◆ Composite samples should be taken over the entire 24 hour period during each test.

Automatic Influent Pump Adjustment Operation (after installation of flow control valve)

- ◆ After installation of the flow control valve to control influent flow, test periods will generally last for 24 hours. Based on information from recent pilot tests with the FF, this duration should provide a minimum of one filter run (i.e. filtering duration to reach maximum inlet pressure). With the exception of extended operational testing (discussed below), changes in test conditions will occur every 24 hours. Whenever possible, the FF should be tested at each specific condition for a 24 hour period. NOTE: The test duration will likely only be 22 hours due to setup and preparation time for the next testing condition.
- ◆ Test conditions started on Friday should be continued in automatic mode through the weekend. Note that composite samples should still be taken over the initial 24 hour period of testing.
- ◆ Composite samples for each test condition are to be taken over a complete test duration. It is anticipated that each trial will be run from the start of an operational day to the next operational day. Therefore, the composites for a specific test condition should be taken for the duration of the test period.

Wash Cycle Optimization

After initial review of proposed testing and performance goals of the pilot testing, it is proposed that wash cycle parameters be kept constant during the pilot testing. Based on the performance goals established for the fuzzy filter pilot unit, it is not necessary to optimize the backwash cycles for wash water quantity during this testing. The performance goals established for the testing of the fuzzy filter included a goal that wash cycle waste be less than 8 percent of the total treated water.

Based on the wash cycle parameters discussed above, even at a filter hydraulic loading rate of 5 gpm/ft² (20 gpm total flow), the wash cycle waste is approximately 8% of the treated water flow when the filter run time between wash cycles is 12 hours or greater. At higher loading rates, the wash water waste criteria can be met at significantly lower filter run times. Therefore, backwash parameters will not be varied during the pilot testing of the FF. Changes in backwash procedure should only be considered when noticeable increases in clean bed headloss are observed. If time permits, additional testing may be considered to evaluate options for reducing wash water waste during filter operation.

Primary and Tertiary Testing Without Chemical Addition

Operational Parameter Evaluation

This period of testing will evaluate FF performance under differing hydraulic loading rates and bed compression ratios. Bed compression ratios will be held constant while hydraulic loading rates are varied. After testing at a full range of hydraulic loading rates, bed compressions will be changed and the hydraulic loading rate variation will be repeated. New testing conditions will input at the beginning of each operational day. The testing conditions will be tested for a period of 24 hours.

Extended Operation Testing

During this period of testing, the fuzzy filter unit will be operated for an extended period of time to evaluate long-term performance. Performance of the filter under transient conditions representative of individual unit backwash will be tested throughout the extended period. Once every six hours, influent flowrates will be increased by 33% for one half hour to simulate backwash conditions. The PLC should be modified to allow these increases of flow automatically. Testing conditions (i.e. hydraulic loading rate and bed compression ratios) for the extended operations testing will be chosen based on pilot testing data during the operation parameter evaluation and analysis and the performance goals discussed in previous sections of this plan.

Since loading rates and compression ratios will not be changed on a daily basis, the filter should not be manually backwashed. Rather, the automatic backwashing as operational conditions require should be allowed to continue unaltered through the test period. Data from this period will be used to determine repeatability of performance over extended periods and performance of the unit under increased loading conditions representative of full scale operation at the West Point WWTP.

Primary and Tertiary Testing With Chemical Addition

The objective of this phase of testing is to evaluate filter performance in combination with coagulants for increased BOD, TSS, and P removal (primary application) and ability to meet Class A reuse requirements and nutrient removal goals (tertiary application).

Coagulant Jar Testing

Jar testing of different coagulants and polymers should be performed prior to this phase (separate testing for tertiary and primary) to determine optimum doses for three coagulants: alum, polyaluminum chloride (PACl), and ferric chloride. Optimum coagulant doses should be determined based on supernate turbidity (TSS in case of primary), and ortho-phosphorous (or total phosphorous). Testing will focus on the use of alum and PACl. If time permits, ferric chloride will be tested. If necessary to meet testing objectives, particularly in the case of tertiary operation, polymer use in conjunction with coagulants may be evaluated. Polymers to be used and required testing will be determined as the need arises during the test periods.

Coagulant Testing

During this testing period, testing will focus on the use of two coagulants: alum and PACl. Doses of these coagulants determined to be most effective in the jar testing proposed above will be tested under varying operational conditions in both tertiary and primary applications. The objective of this testing is to assess filter performance, including increased TSS, BOD, and P removal with coagulant addition and the higher solids loading rates that result from the coagulation / flocculation process. The primary protocol that will be followed for coagulant testing will focus on two testing objectives, in the following order of importance:

1. Determine the operational parameters of the pilot test unit that meet testing objectives using optimal polymer doses determined during jar testing.
2. Modify coagulant dose to optimize coagulant usage.

The need to optimize coagulant dose and testing with ferric chloride will be evaluated during the testing period, based on available time and previously collected data.

Intensive media cleaning may be required when changes in coagulants added are made. The criteria discussed in previous sections should be used to evaluate the need for intensive cleaning.

Extended Operation Testing

The best performing coagulant from the coagulant testing period will be tested over an extended period of time to assess long term performance. Optimum loading rates and bed compression ratios determined from the coagulant testing period will be used during this period. During the initial phase of extended operation testing, coagulant doses will be adjusted to optimize coagulant usage. This phase of testing will include increases in loading rates similar to those discussed for testing without chemical application to simulate single unit backwashing during full scale operation. Coagulant feed will also be modified to simulate full loss of coagulant dose to simulate problems in full scale operation with chemical feed equipment.

An overview of the testing plan for each phase is shown in Table 3. A detailed summary of the testing plan is included in Table 4, attached to this plan. The testing plan will be adjusted based on results achieved. Based test observations, it may be possible to consolidate periods of

testing and/or incorporate additional tests to assess filter performance. Conference calls will be used to facilitate the evaluation process.

Table 3. Proposed Testing Phases and Breakdown of Testing Periods

Phase	Expected Phase Duration	Breakdown of Testing Period
Phase 1 – Primary Treatment Without Chemical Addition	1 month	Weeks 1-3: Operation Parameter Evaluation Week 4: Extended Operation
Phase 2 – Primary Treatment with Chemical Addition	1 month	Weeks 1-3: Coagulant Testing Week 4: Extended Operation
Phase 3 – Tertiary Treatment with Chemical Addition	2 months	Weeks 1-6: Coagulant Testing Weeks 7-8: Extended Operation
Phase 4 – Tertiary Treatment without Chemical Addition	1 months	Weeks 1-3: Operation Parameter Evaluation Week 4: Extended Operation

Sampling and Analysis

Primary and Tertiary Testing Without Chemical Addition

Operation Parameter Evaluation

Testing during this period will include periodic composites for TSS, COD_i, and COD_s and less frequent samples for TP, OP, BOD, TKN, and NH₃ (primary testing only). Nutrient sampling and analysis will be performed to establish baseline removals for comparison with removals achieved during coagulant addition. Primary analysis of data will include influent and effluent turbidity during filter runs, removal efficiencies of all parameters tested, and inlet pressure during operation. Stored TSS will also be calculated based on length of filter run and average TSS composites to establish storage capacity of the filter under each bed compression ratio.

Extended Operation

Testing during this period will include periodic composites for TSS, COD_i, and COD_s and less frequent samples for TP, OP, BOD, TKN, and NH₃ (primary testing only). Primary analysis of data will include influent and effluent turbidity during filter runs (tertiary treatment only), removal efficiencies of all parameters tested, and inlet pressure during operation. Stored TSS will also be calculated based on length of filter run and average TSS composites taken on the influent and effluent. Grab samples will be taken for total coliform and microbial analysis during two days of extended operation testing to assess removals.

Primary and Tertiary Testing With Chemical Addition

Coagulant Testing

Testing during this period will include periodic composites for TSS, COD_t, and COD_s and less frequent samples for TP, OP, BOD, TKN, and NH₃ (primary testing only). Primary analysis of data will include influent and effluent turbidity during filter runs, removal efficiencies of all parameters tested, and inlet pressure during operation.

Extended Operational Testing

Testing during this period will include periodic composites for TSS, COD_t, and COD_s and less frequent samples for TP, OP, BOD, TKN, and NH₃ (primary testing only). Primary analysis of data will include influent and effluent turbidity during filter runs (tertiary treatment only), removal efficiencies of all parameters tested, and inlet pressure during operation. Stored TSS will also be calculated based on length of filter run and average TSS composites taken on the influent and effluent.

A summary of samples that will be taken during each day of testing is included in Table 4, attached to this plan.

Schedule

The proposed testing schedule is shown in Table 4, attached to this document. .

Issues for discussion

1. Is monitoring of turbidity on influent and effluent of fuzzy filter unit feasible. Can we use a high range turbidity unit on the influent of the fuzzy filter unit in the primary application?
2. Is periodic adjustment of influent pumping (i.e. once per hour or 2 hours - 24 hours per day) feasible? If not, initial testing will need to be reduced to 8 hours per day.
3. How can we verify that adequate coagulation / flocculation takes place prior to feed to the fuzzy filter?

Roles and responsibilities

County will operate the unit and collect all samples. County West Point Process Lab will do all analyses (except any special tests?) County will maintain the project data management system to include the data obtained for the fuzzy filter. The consultant team (HDR and Black & Veatch) will evaluate the data and distribute the information to the project team. It is anticipated that two conference calls per month will be held to discuss the overall testing program. During the calls, the testing status and review of data occur for the fuzzy filter unit.



On an as needed basis, the County will coordinate a conference call with Schreiber. If possible, these calls will include all project team members listed in the subsequent contacts section. However, since it is difficult to coordinate calls for a large group of people, the level of participation may vary to reduce the coordination effort. At a minimum, Bob Bucher and JB Neethling will participate in these calls.

Contacts

Since this testing is occurring in a very brief period, and many test conditions will be evaluated, it is important to maintain frequent, if not daily communications between King County and the consultant team (HDR and Black & Veatch). The following is a list of the project team members.

King County

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HDR

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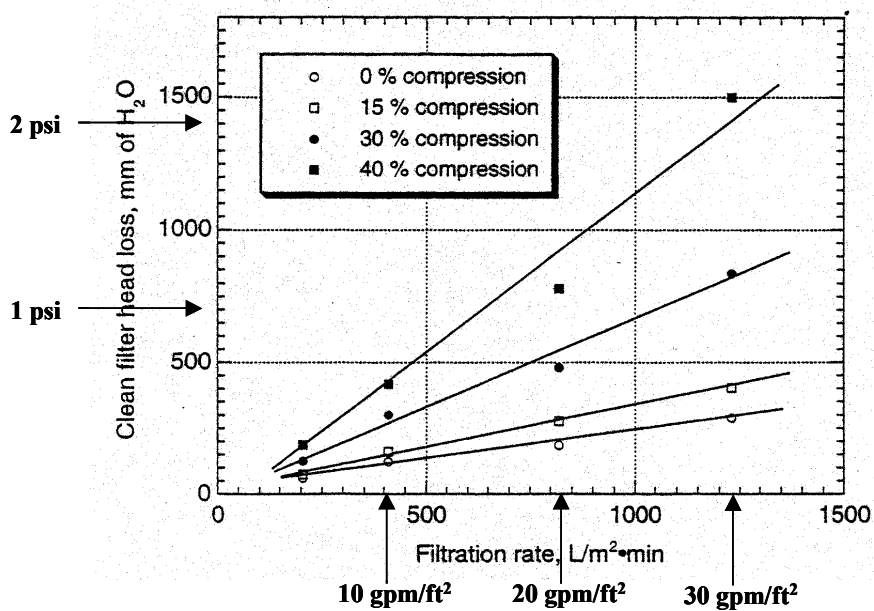
Schreiber

Alan Vogt
205-655-7466

Adrian Corollan, adriancarolan@worldnet.att.net
205-655-7466

Fuzzy Filter Headloss Curve

Clean Bed Headloss for Fuzzy Filter



1 gpm/ft² = ~40 L/m²-min

1 psi = ~700 mm H₂O

NOTE: Add depth of water in filter / 2.307 to values above to calculate initial pressure reading in psi.

From: Caliskaner and Tchobanoglous, 1996. "Evaluation of the Fuzzy Filter Unit for the Filtration of Secondary Effluent."

FUZZY FILTER®

Quarterly Maintenance Media Cleaning Procedure

This procedure shall be performed on a quarterly basis. If chemical addition is used (polymer or flocculating agents) or excessively dirty influent filtering water (algae or grease) is present, this procedure should be performed more frequently. This procedure will be performed in the manual mode of operation.

Procedure:

1. Initiate a normal automatic wash cycle. At the completion of the wash cycle, drain the unit.
2. Initiate manual mode operation, then close effluent valve.
3. In manual mode, raise upper movable plate to the upper limit switch position.
4. Fill the unit with influent water or a clean water source to the bottom of the effluent pipe. Close the influent flow valve. Measure the distance from the bottom of the filter to the bottom of the effluent pipe and use square area of the filter to calculate the volume of water present in the filter. This volume will be used in Step 5.
5. Using the volume of water present in the filter (calculated in Step 4), add enough chlorine or bleach to achieve a chlorine concentration of 200 mg/L. Add chlorine or bleach through the top hatch of the filter.
6. In manual mode, open one (1) air valve (either one of the two) and turn on the wash blower for **5 to 10** minutes. Turn off the wash blower and close the air valve. Open the other air valve and turn on the wash blower for **5 to 10** minutes. Turn off the wash blower and close the air valve.
7. Allow the media to soak for **20 to 30** minutes.
8. Repeat Steps 6 and 7 for 3 hours.
9. In manual mode, **open the effluent flow valve. Then open the influent flow valve.** Initiate an automatic wash cycle and allow the filter to return to normal automatic operation.

King County Water Reuse Demonstration Project
Table 4. Original Fuzzy Filter Sampling Plan and Schedule

Revised 11/01/01

Test Phase	Date	Hydraulic Loading Rate (gpm/sf)	Filter Influent Feed Rate (gpm)	Bed Comp. (%)	Influent/Effluent (one per location): S1, S14 for influent, S4, S8 for effluent												Grab Samples (see notes below)						
					Daily Composite Samples										Continuous (PLC)								
					TSS	VSS	COD ₁	COD ₂	BOD ₁	BOD ₂	TP	OP	TKN	NH ₃	Pressure	Turbidity	Metals	TC	HPC	Alk	Temp (l&E)	pH (l&E)	
Preliminary																							
Unit shakedown - preliminary operations ^a					9/21-10-28	20-30	80-120	20-30								x	x						
Primary Without Chemical Application																							
Weeks 1-3 - Op Parameter Evaluation					10/28	5	20	10	2		2					x	x				2	2	
Note: Previous week used for unit shakedown					10/29	10	40	10	2		2					x	x						
	10/30	15	60	10	2		2		2		2					x	x						
	10/31	20	80	10	2		2									x	x						
	11/1	10	40	20	2		2									x	x						
	11/4	15	60	20	2		2									x	x						
	11/5	20	80	20	2		2		2		2					x	x			2	2		
Add. Op. Testing if needed					11/6	10	40	30	2		2					x	x						
	11/7	15	60	30	2		2									x	x						
	11/8	20	80	30	2		2		2		2					x	x						
Extended Operation (1)					11/11	TBD	TBD	TBD	2		2		2			x	x				2	2	
Note: Consider testing peak parameters ¹¹					11/12	TBD	TBD	TBD	2		2					x	x						
Note: 11/11 and 11/12 potential float days for					11/13	TBD	TBD	TBD	2		2		2	2	2	x	x	2	2(9)	2(9)			
	11/14	TBD	TBD	TBD	2		2									x	x						
	11/15	TBD	TBD	TBD	2		2	2	2	2	2	2	2	2	x	x		2(9)	2(9)	2	2	2	
Primary With Chemical Application																							
Coagulant Testing																							
Coag Dose 1(3)					11/18	10	40	10	2		2					x	x						
	11/19	15	60	10	2		2									x	x						
	11/20	20	80	10	2		2		2		2					x	x						
	11/21	10	40	30	2		2									x	x						
					11/22																		
	11/25	15	60	30	2		2									x	x			2	2	2	
	11/26	20	80	30	2		2	2	2	2	2					x	x						
Coag Dose 2 (3)					11/27	10	40	10	2		2					x	x						
	11/28	15	60	10	2		2									x	x						
	11/29	20	80	10	2		2		2		2					x	x						
	12/2	10	40	30	2		2									x	x			2	2	2	
	12/3	15	60	30	2		2									x	x						
	12/4	20	80	30	2		2	2	2	2	2					x	x						
Coag Dose 3? Ferric (5)					12/5	TBD	TBD	TBD	2		2					x	x						
(or coagulant dose optimization)					12/6	TBD	TBD	TBD	2		2					x	x						
	12/9	TBD	TBD	TBD	2		2		2		2					x	x			2	2	2	
Ext. Op (1) Coag dose optimization (6)					12/10	TBD	TBD	TBD	2		2		2	2		x	x						
Coag dose optimization (6)					12/11	TBD	TBD	TBD	2	2	2	2	2		x	x							
	12/12	TBD	TBD	TBD	2		2	2	2	2	2	2	2	2	x	x	2	2(9)	2(9)				
Loss of coagulant dose(10)					12/13	TBD	TBD	TBD	2		2		2	2	2	x	x	2	2(9)	2(9)	2	2	2

King County Water Reuse Demonstration Project
Table 4. Original Fuzzy Filter Sampling Plan and Schedule

Test Phase	Date	Hydraulic Loading Rate (gpm/sf)	Filter Influent Feed Rate (gpm)	Bed Comp. (%)	Influent/Effluent (one per location): S1, S14 for influent, S4, S8 for effluent												Grab Samples (see notes below)							
					Daily Composite Samples										Continuous (PLC)		Metals	TC	HPC	Alk	Temp (l&E)	pH (l&E)		
					TSS	VSS	COD _l	COD _s	BOD _l	BOD _s	TP	OP	TKN	NH ₃	Pressure	Turbidity								
Tertiary with Chemical Application																								
Weeks 1-6- Coagulant Testing																								
Coagulant Dose 1(3)					12/16	20	80	20	2		2						x	x						
					12/17	10	40	20	2		2					x	x							
					12/18	30	120	20	2		2		2	2		x	x							
					12/19	20	80	30	2		2					x	x							
					12/20	10	40	30	2		2					x	x			2	2	2		
					12/23	30	120	30	2		2	2	2	2	2	x	x							
					12/24																			
					12/25																			
					12/26	20	80	10	2		2					x	x							
					12/27	10	40	10	2		2					x	x							
					12/30	30	120	10	2		2		2	2		x	x							
Opt coagulant testing / extra conditions (4)					12/31	TBD	TBD	TBD	2		2					x	x				2	2	2	
					1/1																			
					1/2	TBD	TBD	TBD	2		2						x	x						
					1/3	TBD	TBD	TBD	2		2	2	2	2	2		x	x						
					1/6	TBD	TBD	TBD	2		2						x	x						
Coagulant Dose 2 (3)					1/7	20	80	20	2		2						x	x						
					1/8	10	40	20	2		2						x	x			2	2	2	
					1/9	30	120	20	2		2		2	2	2		x	x						
					1/10	20	80	30	2		2						x	x						
					1/13	10	40	30	2		2						x	x			2	2	2	
					1/14	30	120	30	2		2	2	2	2	2		x	x						
					1/15	20	80	10	2		2						x	x						
					1/16	10	40	10	2		2						x	x						
					1/17	30	120	10	2		2		2	2	2		x	x			2	2	2	
Opt coagulant testing / extra conditions (4)					1/20	TBD	TBD	TBD	2		2						x	x						
					1/21	TBD	TBD	TBD	2		2						x	x						
					1/22	TBD	TBD	TBD	2		2	2	2	2	2		x	x						
					1/23	TBD	TBD	TBD	2		2						x	x						
Weeks 7-8 Extended Operation (1)																								
Coag dose optimization (6)					1/24	TBD	TBD	TBD	2		2	2	2	2	2	2		x	x			2	2	2
Coag dose optimization (6)					1/27	TBD	TBD	TBD	2		2		2	2	2	2		x	x					
Coag dose optimization (6)					1/28	TBD	TBD	TBD	2		2	2	2	2	2	2		x	x					
Coag dose optimization (6)					1/29	TBD	TBD	TBD	2		2		2	2	2	2		x	x					
Coag dose optimization (6)					1/30	TBD	TBD	TBD	2		2	2	2	2	2	2		x	x					
					1/31	TBD	TBD	TBD	2		2		2	2	2	2		x	x			2	2	2
					2/3	TBD	TBD	TBD	2		2	2	2	2	2	2	2	x	x	2	2(9)	2(9)		
					2/4	TBD	TBD	TBD	2		2		2	2	2	2		x	x					
Loss of coagulant dose (10)					2/5	TBD	TBD	TBD	2		2	2	2	2	2	2	2	x	x	2	2(9)	2(9)		
Unit cleanup / float?					2/6	TBD	TBD	TBD	2		2		2	2	2	2		x	x					

King County Water Reuse Demonstration Project
Table 4. Original Fuzzy Filter Sampling Plan and Schedule

Revised 11/01/01

Test Phase	Date	Hydraulic Loading Rate (gpm/sf)	Filter Influent Feed Rate (gpm)	Bed Comp. (%)	Influent/Effluent (one per location): S1, S14 for influent, S4, S8 for effluent												Grab Samples (see notes below)							
					Daily Composite Samples												Continuous (PLC)							
					TSS	VSS	COD _i	COD _s	BOD _i	BOD _s	TP	OP	TKN	NH ₃	Pressure	Turbidity	Metals	TC	HPC	Alk	Temp (l&E)	pH (l&E)		
Tertiary with no Chemical Application																								
Weeks 1-3 Operation Parameter Testing					2/7	20	80	20	2		2						x	x				2	2	
					2/10	10	40	20	2		2							x	x					
					2/11	30	120	20	2				2			x	x							
					2/12	20	80	30	2		2						x	x						
					2/13	10	40	30	2		2					x	x							
					2/14	30	120	30	2		2	2	2	2			x	x				2	2	
					2/17	20	80	10	2		2					x	x							
					2/18	10	40	10	2		2						x	x						
					2/19	30	120	10	2		2		2			x	x							
					2/20	20	80	35	2		2						x	x						
					2/21	10	40	35	2		2					x	x				2	2		
					2/24	30	120	35	2		2	2	2	2			x	x						
Week 4 - Extended Operation (1)					2/25	TBD	TBD	TBD	2		2	2	2	2		x	x				2	2		
					2/25	TBD	TBD	TBD	2		2	2	2	2	2		x	x	2	2(9)	2(9)			
					2/26	TBD	TBD	TBD	2		2						x	x						
					2/27	TBD	TBD	TBD	2		2	2	2	2	2		x	x	2	2(9)	2(9)			
Totals					172	0		172	36	76	36	76	76	16	8	0	0	14	0	0	24	38	38	

(1) Increase flowrate to 133% of chosen flowrate once every 6 hours for one half hour.

(3) During testing, dosages and testing conditions may be updated to optimize filter runs/coagulant dose

(4) During this phase, will try to adjust polymer dosage at optimum operating conditions and / or do additional operating conditions.

(5) This period may be used to test ferric chloride or as additional testing days for first two coagulant doses.

(6) Will adjust coag dose for several runs to see if performance under operational parameter evaluation can be met with less coag feed.

(8) Use time period to run additional tests as determined based on initial testing.

(9) Take one grab from influent and effluent during middle of filter run. If composites are possible for this - take one composite at influent and effluent.

(10) Stop coagulant dose for 8 hours during test day

(11) If test results do not indicate that we have reached peak unit performance capacity, extended period may be used to test higher compressions and flowrates (i.e. 40% compression and 25-30 gpm /sf loading rate).

King County Water Reuse Demonstration Project - Fuzzy Filter
Appendix A-4 Summary of Test Conditions - Tertiary Treatment with Chemical Addition

NOTES

Spreadsheet contains final summary of test conditions for Tertiary Treatment with Chemical Addition
 See Appendix E for sampling and laboratory analysis performed during each test.

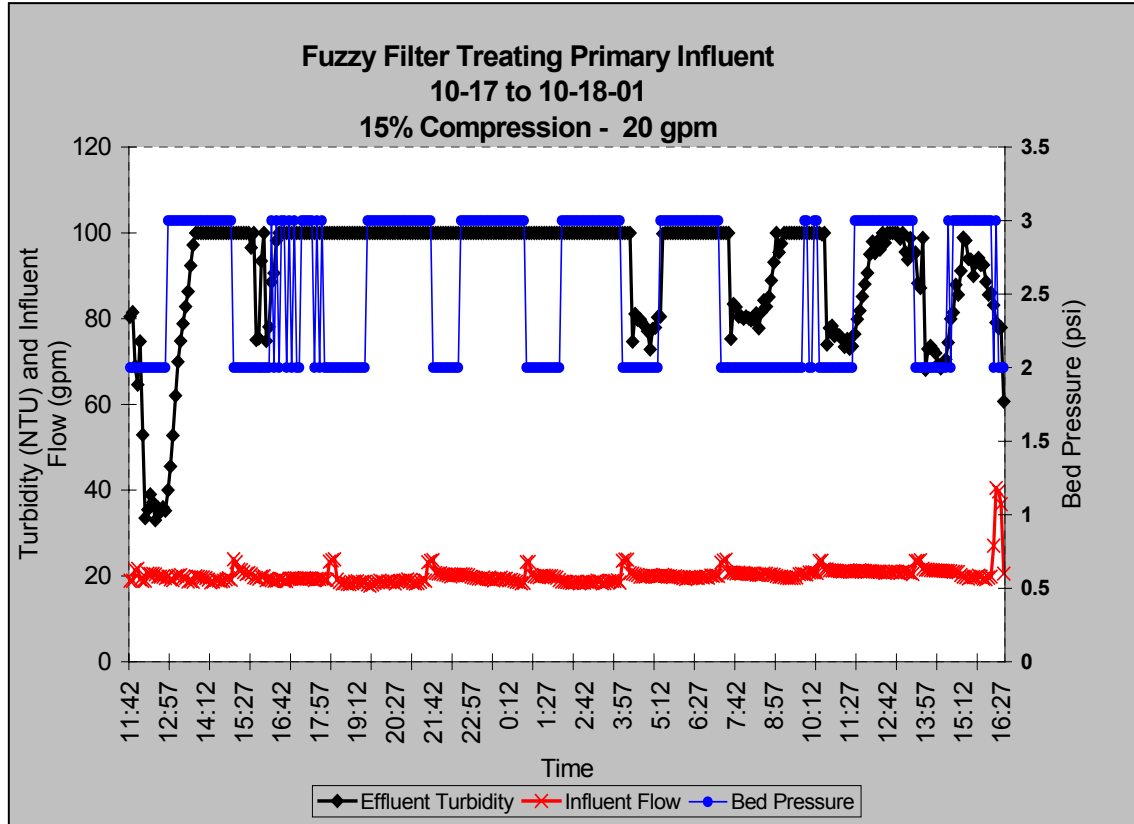
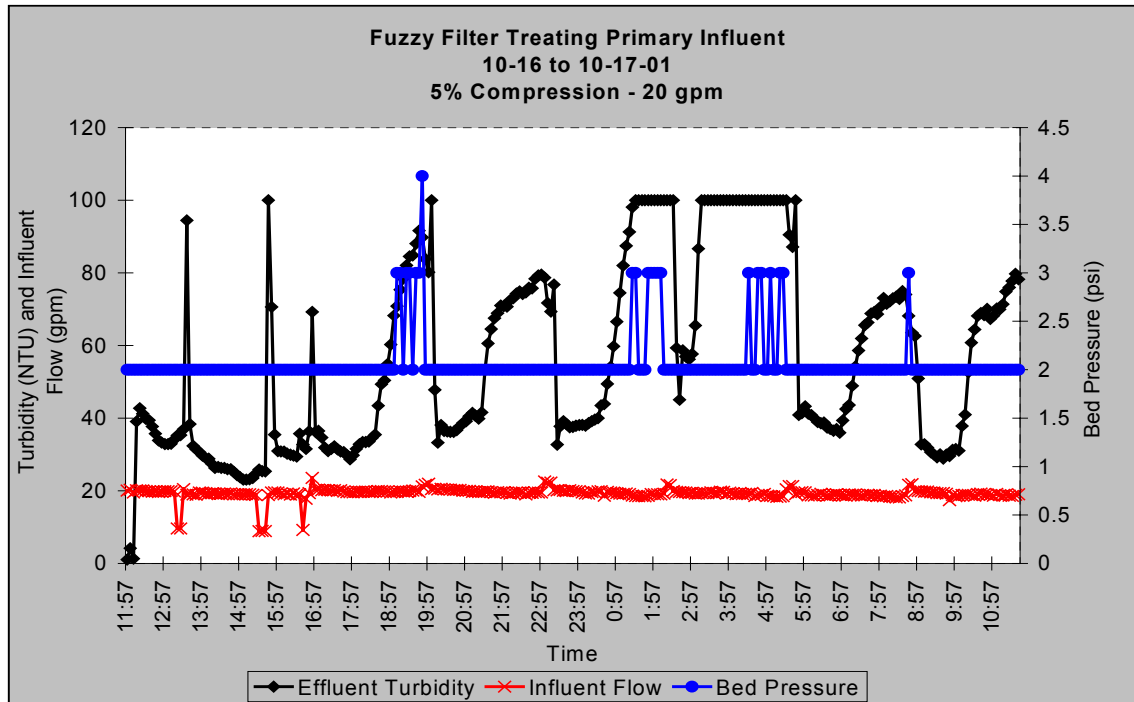
Test Condition Number	Start Date	End Date	Hydraulic Loading Rate (gpm/ft ²)	Bed Compression (%)	Wash Cycle Criteria	Coagulant Addition	Testing Comments
20	1/31/2002	2/5/2002	20	20	1.75 psi above CBP	Alum - 30 mg/L	
21	2/5/2002	2/6/2002	30	20	1.75 psi above CBP	Alum - 30 mg/L	
22	2/6/2002	2/7/2002	10	20	1.75 psi above CBP	Alum - 30 mg/L	Primary bypass during trial
23	2/7/2002	2/8/2002	20	30	1.75 psi above CBP	Alum - 30 mg/L	Primary bypass during trial
24	2/8/2002	2/10/2002	20	20	1.75 psi above CBP	Alum - 30 mg/L	
25	2/10/2002	2/11/2002	30	20	1.75 psi above CBP	Alum - 30 mg/L	Primary bypass during trial
26	2/11/2002	2/12/2002	20	20	1.75 psi above CBP	Alum - 75 mg/L	
27	2/12/2002	2/13/2002	10	20	1.75 psi above CBP	Alum - 30 mg/L	
31	2/18/2002	2/19/2002	20	20	1.75 psi above CBP	Alum - 30 mg/L	
32	2/19/2002	2/20/2002	10	20	1.75 psi above CBP	Alum - 30 mg/L	
33	2/20/2002	2/22/2002	20	20	1.75 psi above CBP	PACl - 30 mg/L	Primary bypass during trial
34	2/22/2002	2/26/2002	10	20	4 psi	PACl - 30 mg/L	Primary bypass during trial
35	2/26/2002	3/1/2002	10	10	4 psi	PACl - 30 mg/L	
36	3/1/2002	3/4/2002	15	20	4 psi	PACl - 30 mg/L	
37	3/4/2002	3/5/2002	20	20	4 psi	PACl - 30 mg/L	
38	3/5/2002	3/6/2002	20	10	4 psi	PACl - 30 mg/L	
39	3/6/2002	3/8/2002	15	10	4 psi	PACl - 30 mg/L	
40	3/8/2002	3/12/2002	25	10	4 psi	PACl - 30 mg/L	Primary bypass during trial
42	3/13/2002	3/14/2002	30	10	4 psi	PACl - 30 mg/L	
43	3/14/2002	3/15/2002	30	10	4 psi	PACl - 15 mg/L	
45	3/18/2002	3/20/2002	30	10	4 psi	PACl - 15 mg/L	

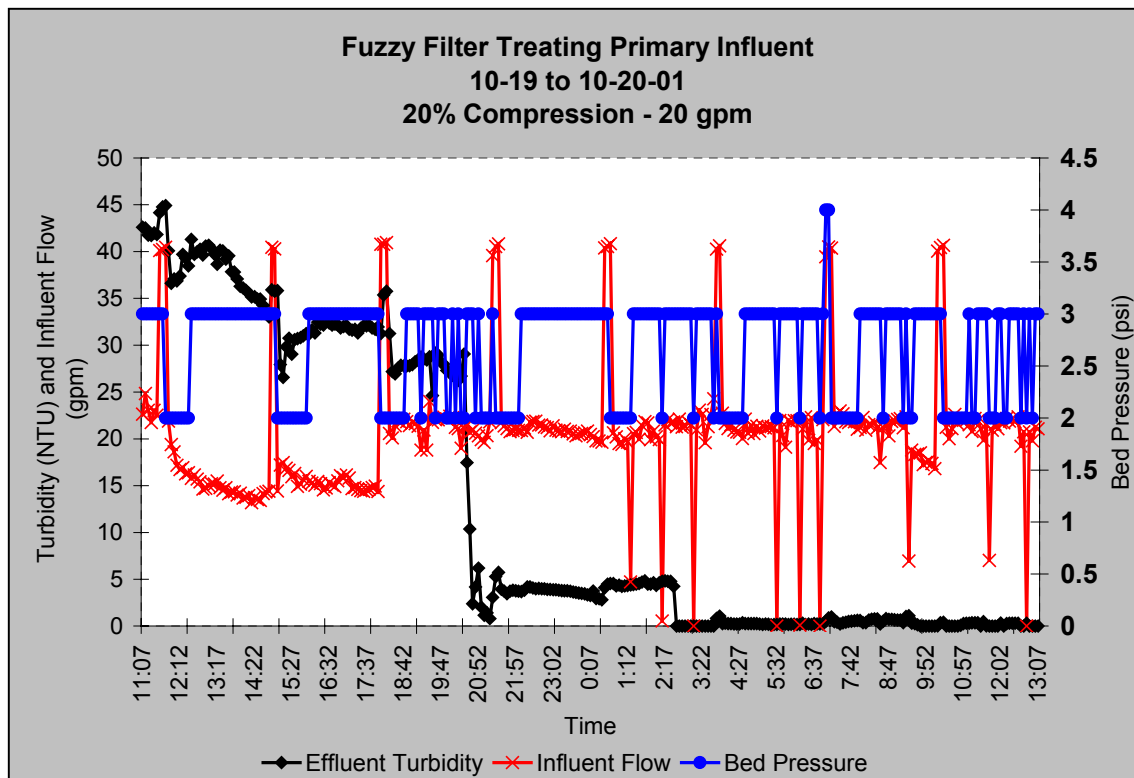
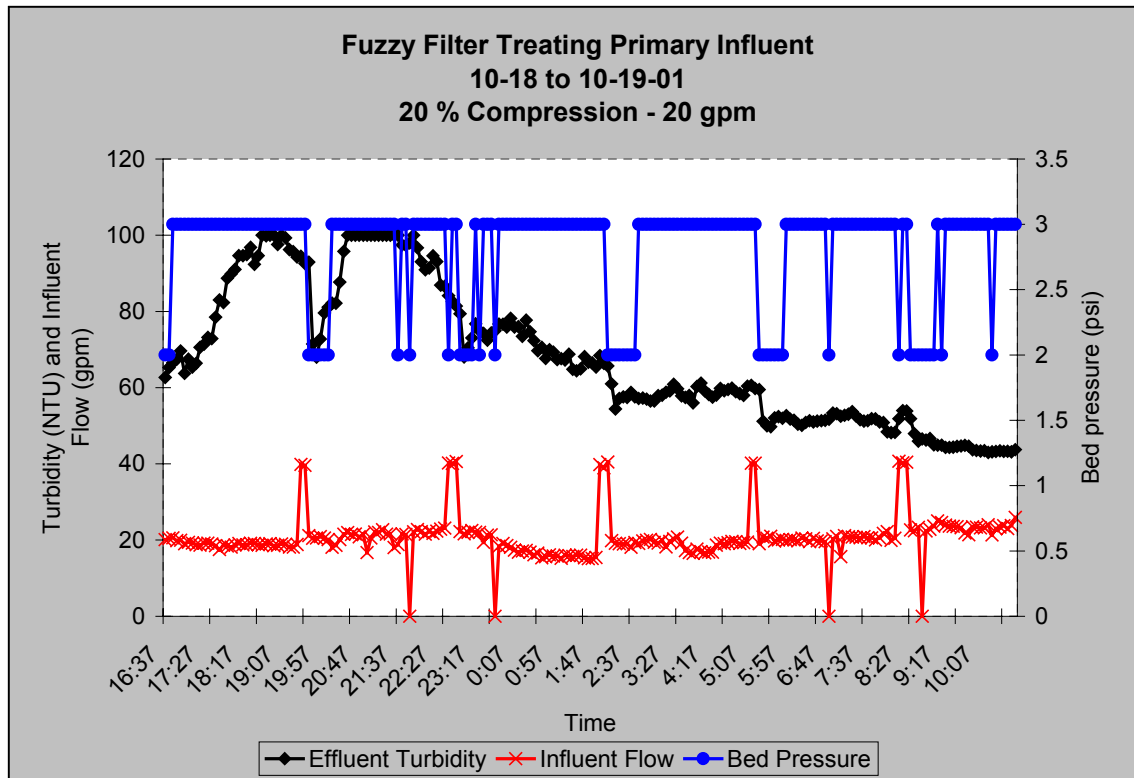
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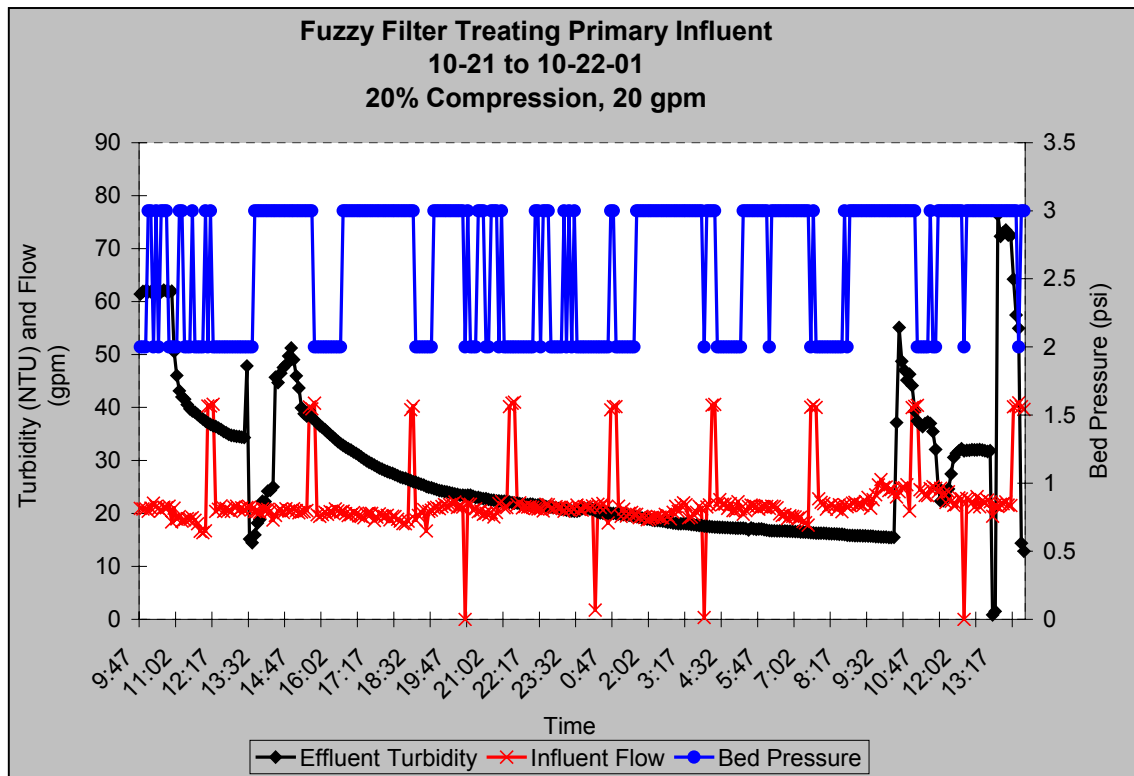
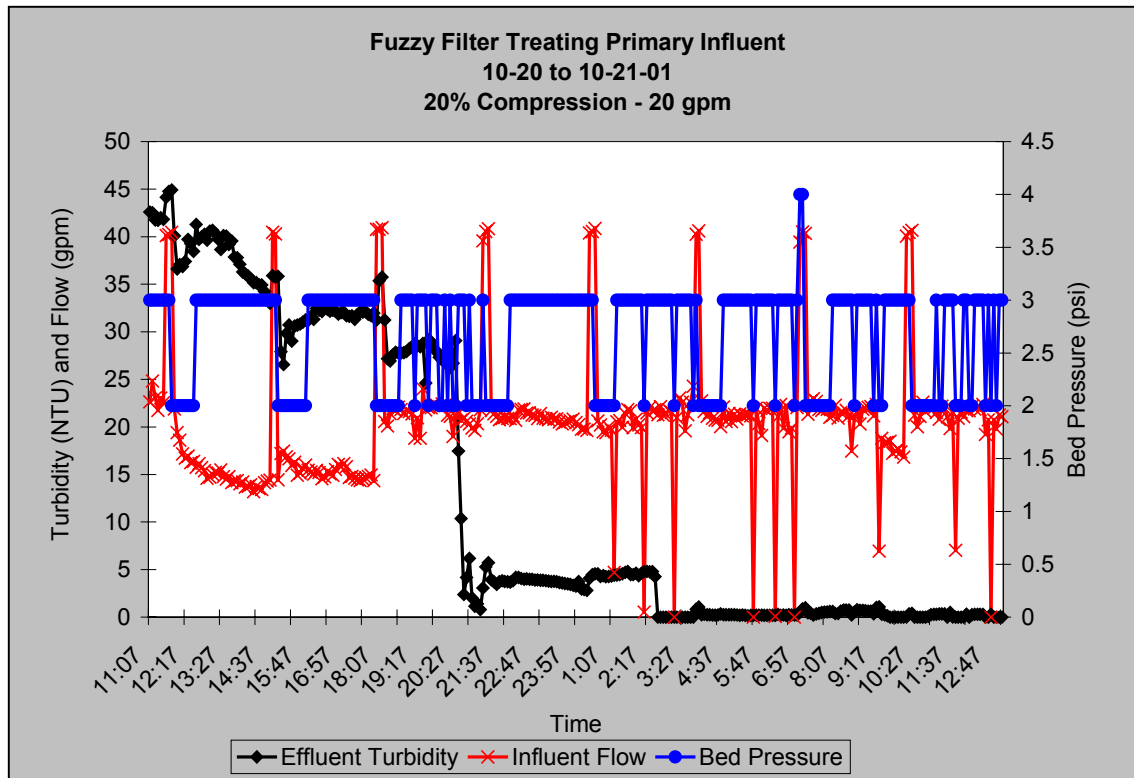
CBP = Clean Bed Filter Influent Pressure

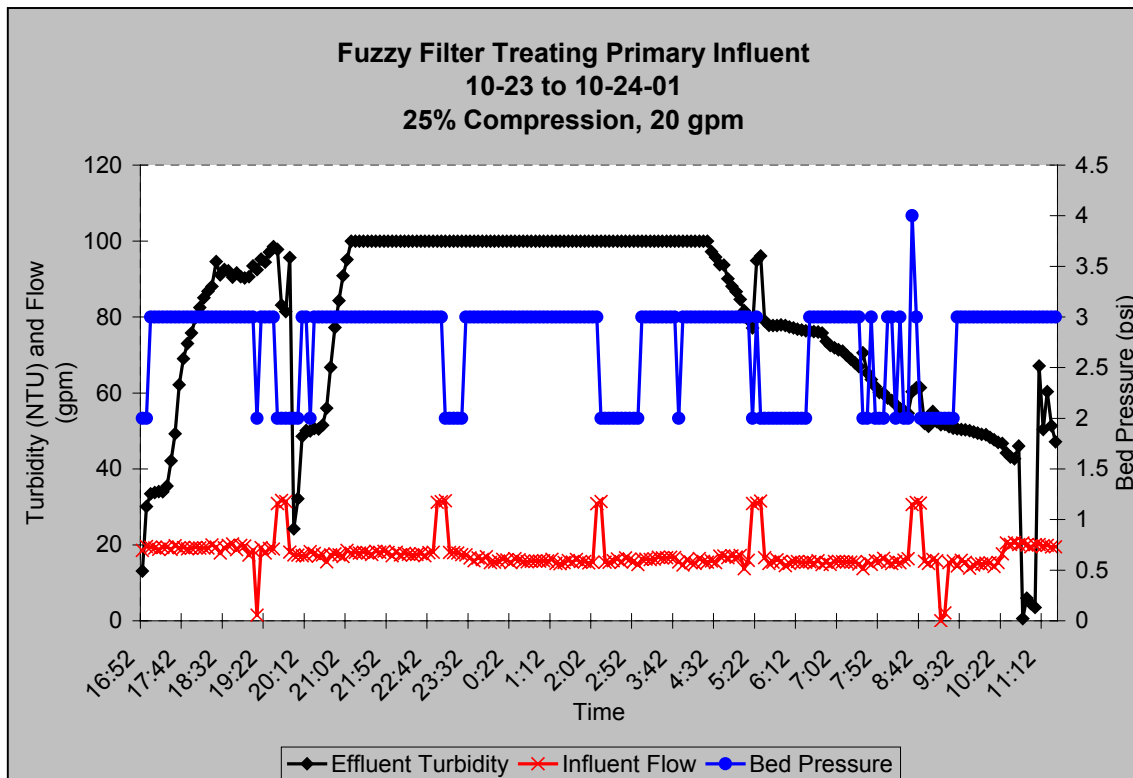
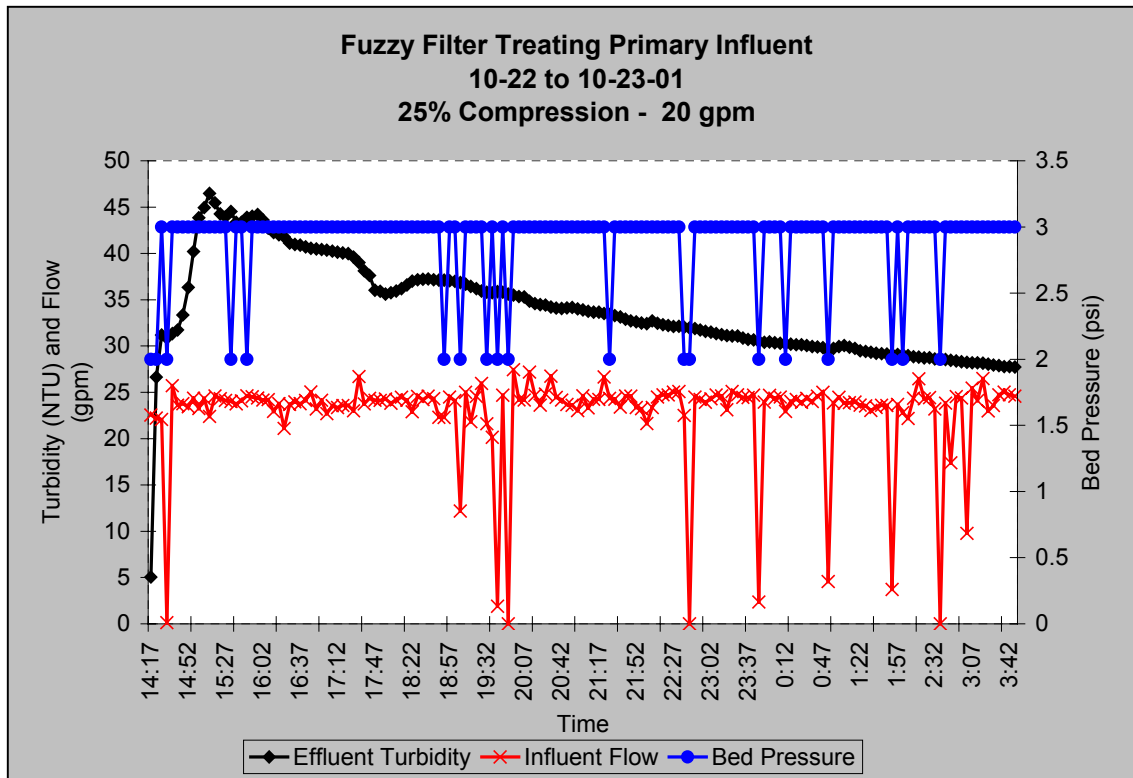


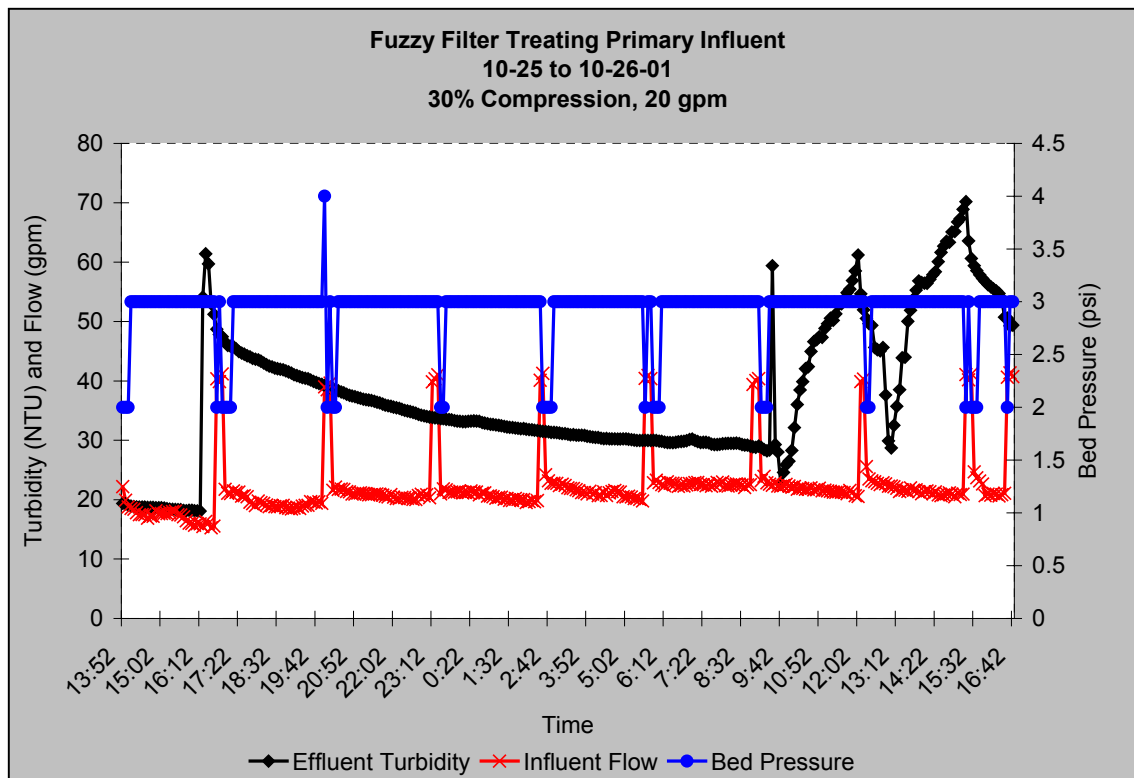
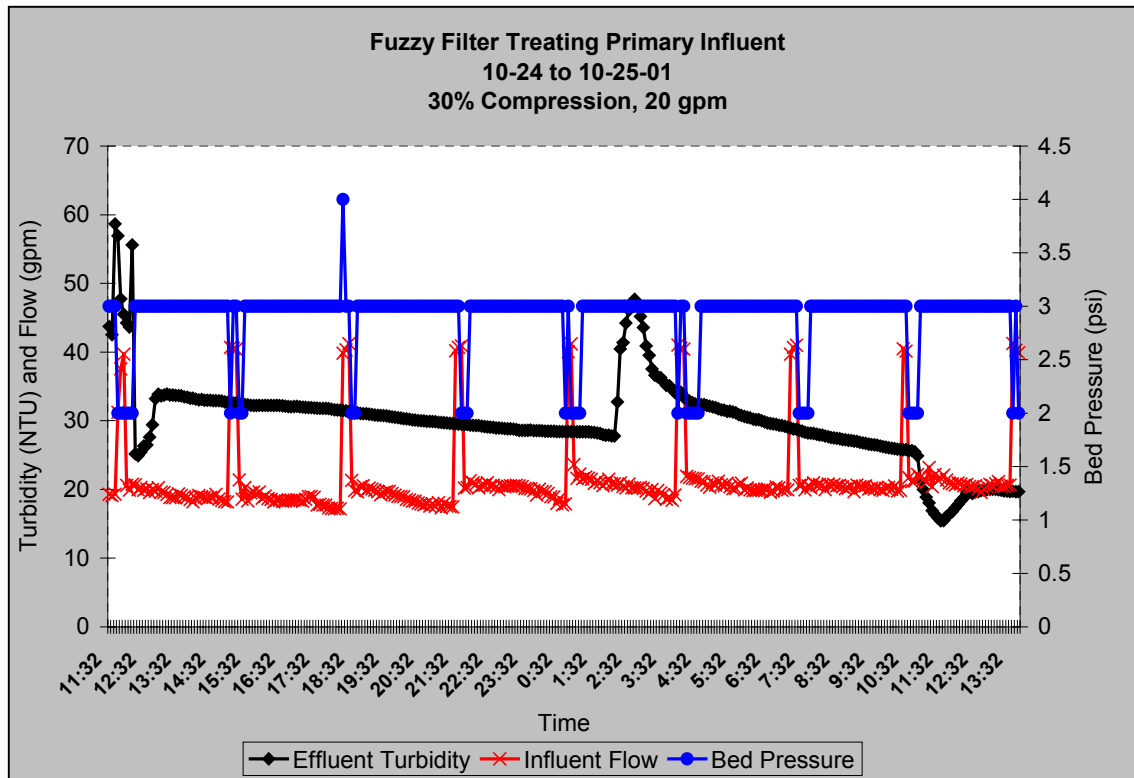
Fuzzy Filter Appendix B Graphs

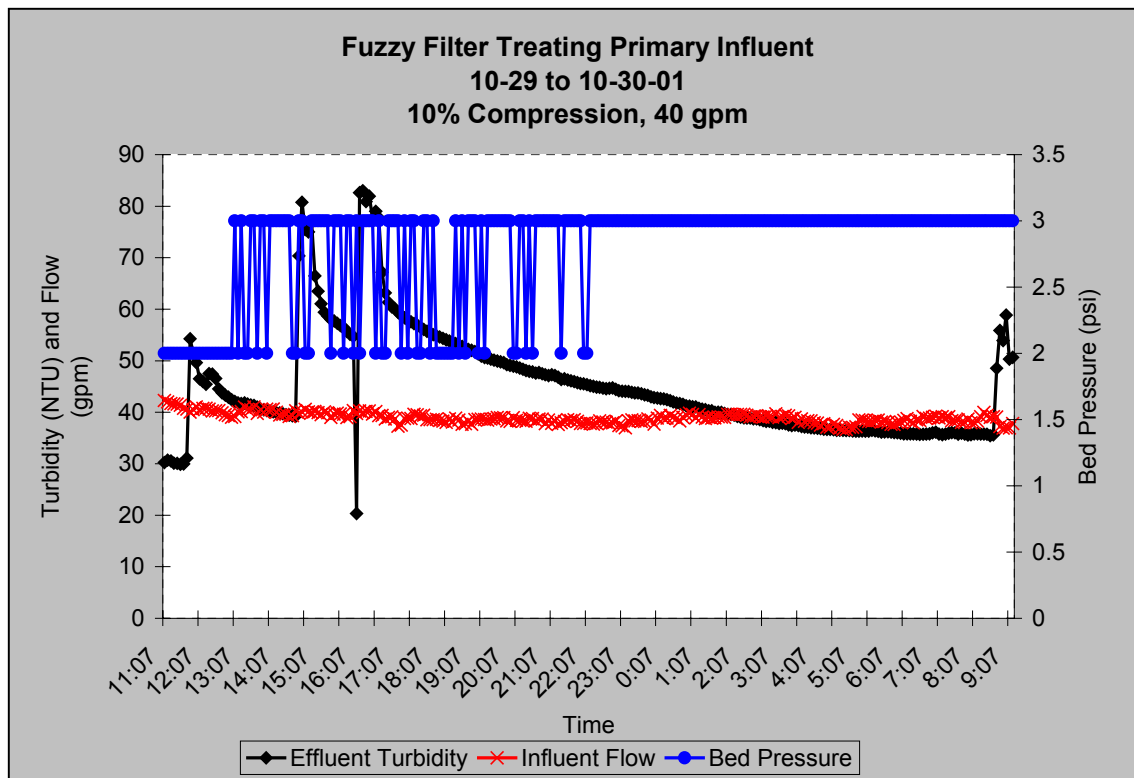
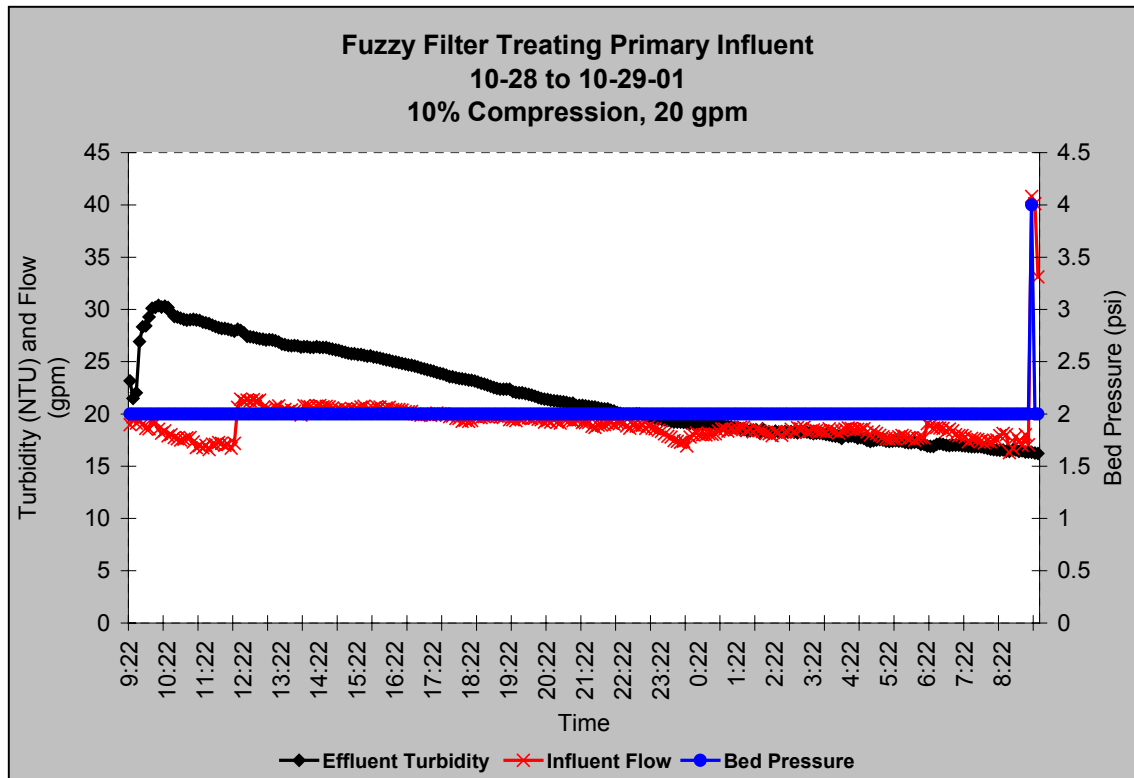


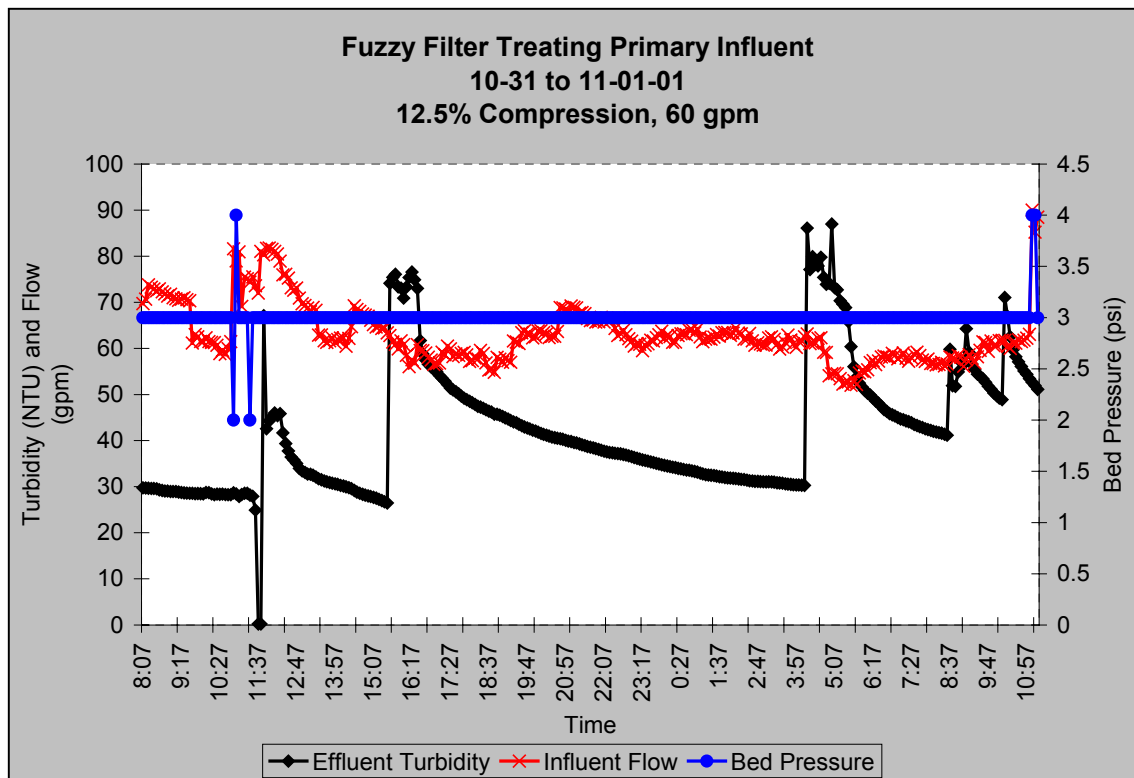
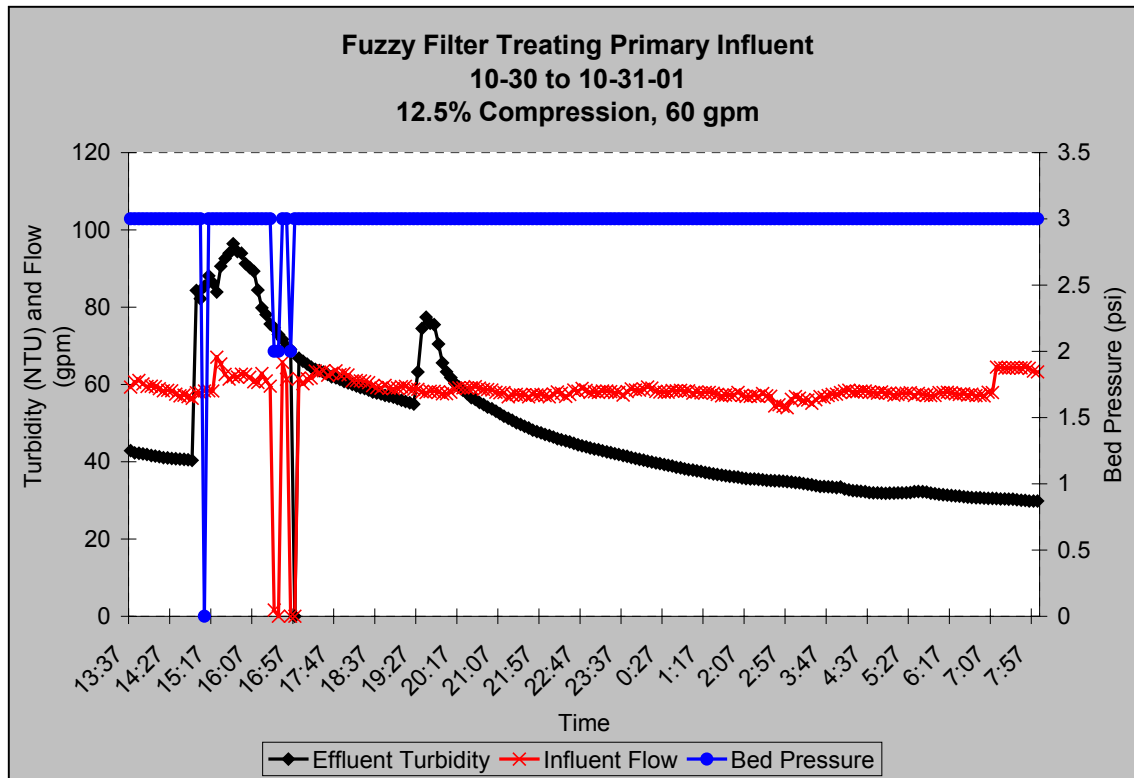


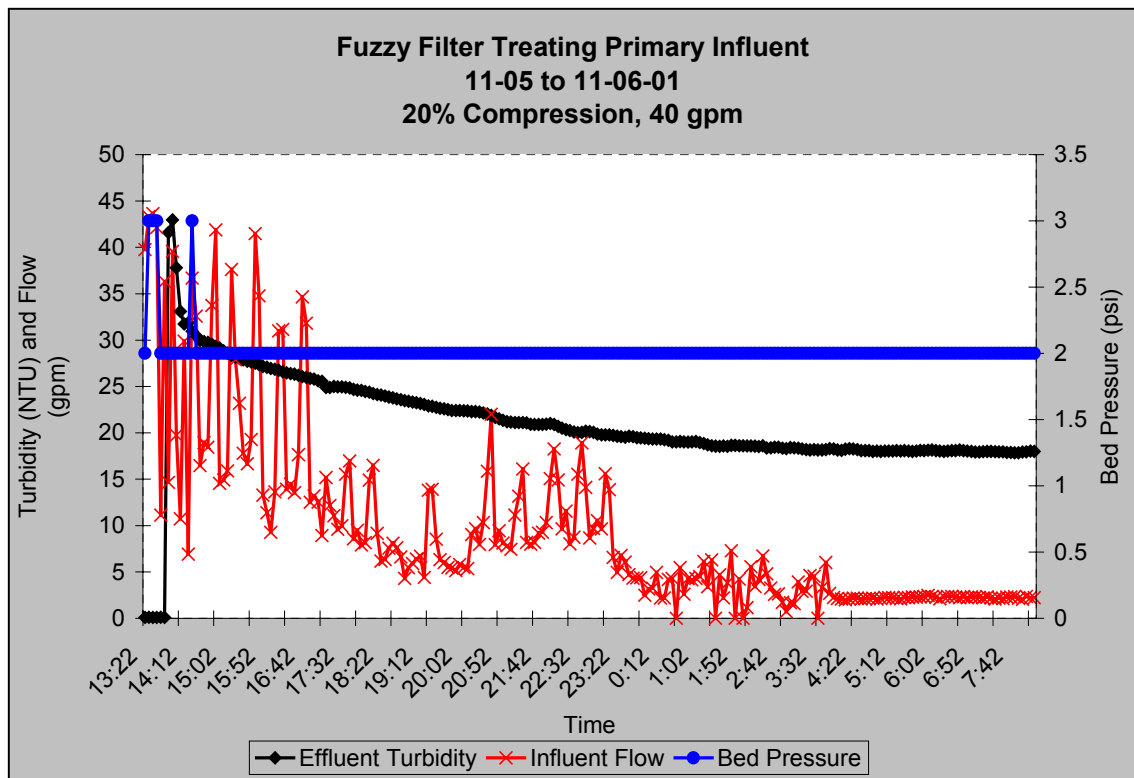
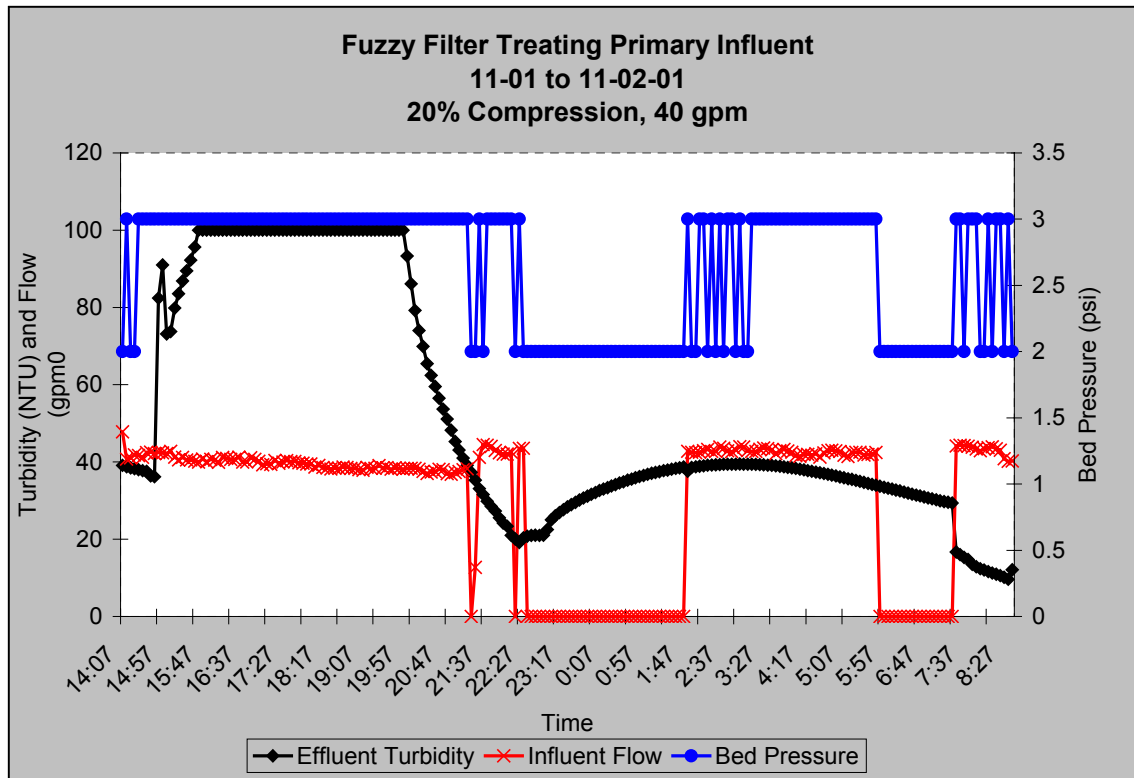


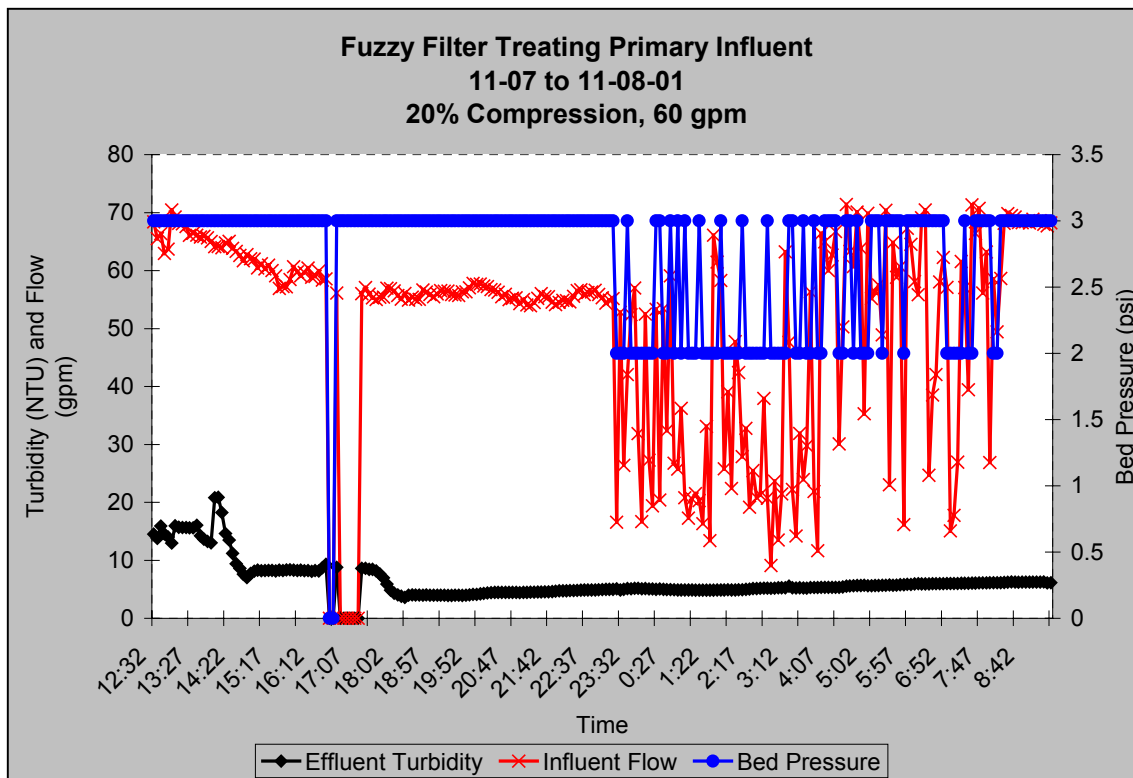
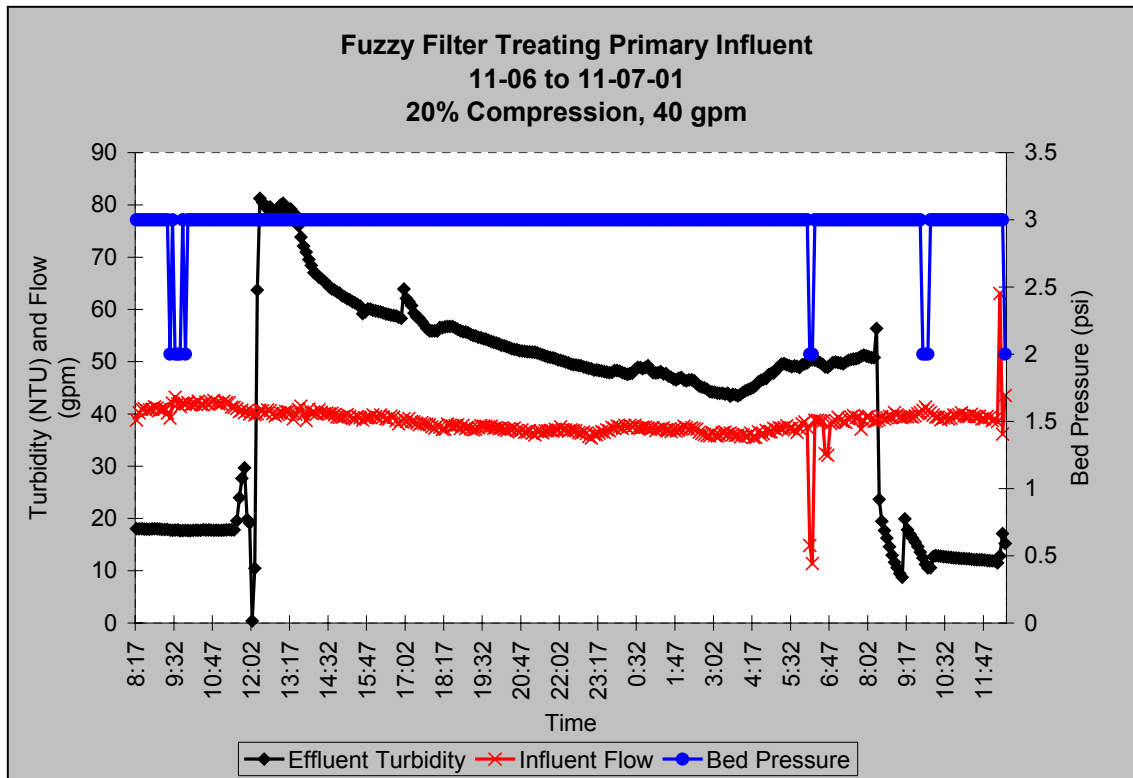


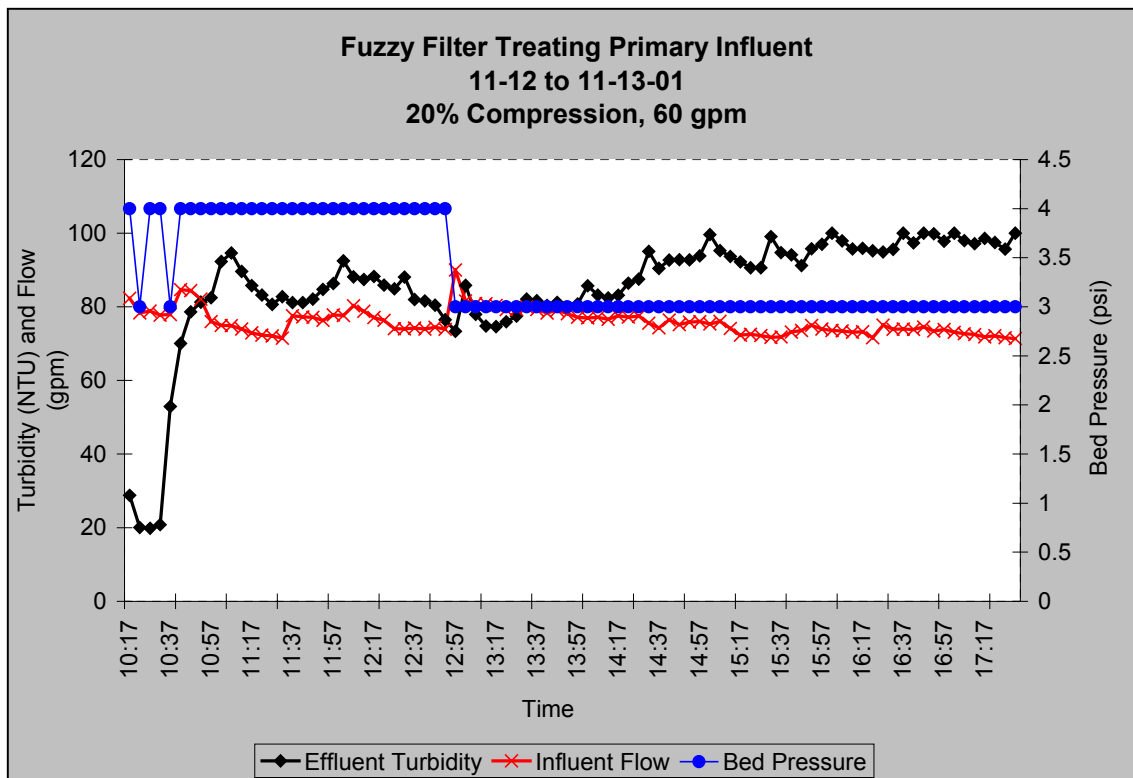
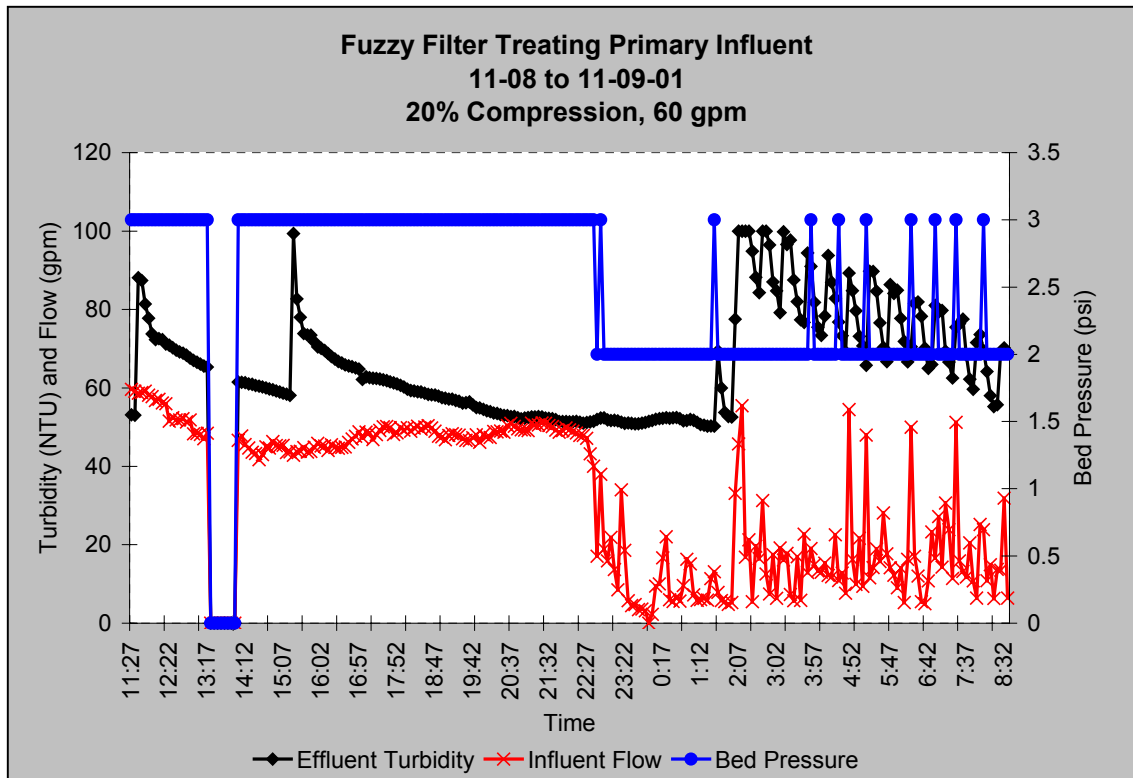


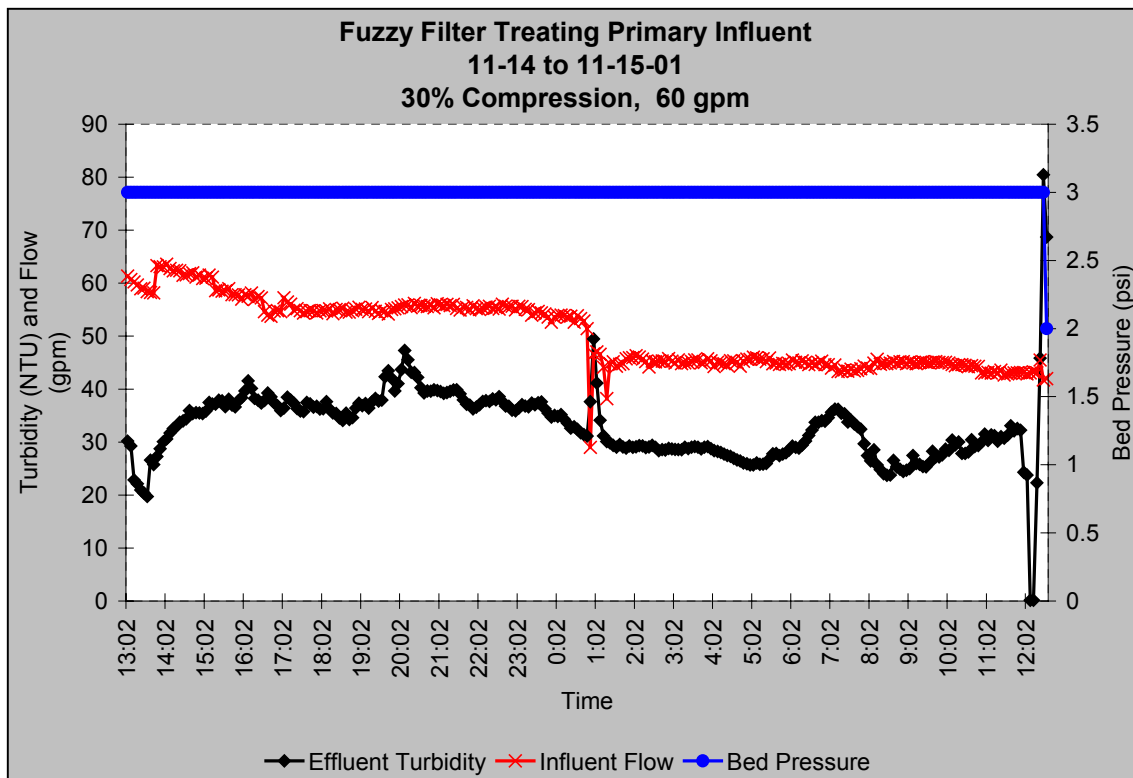
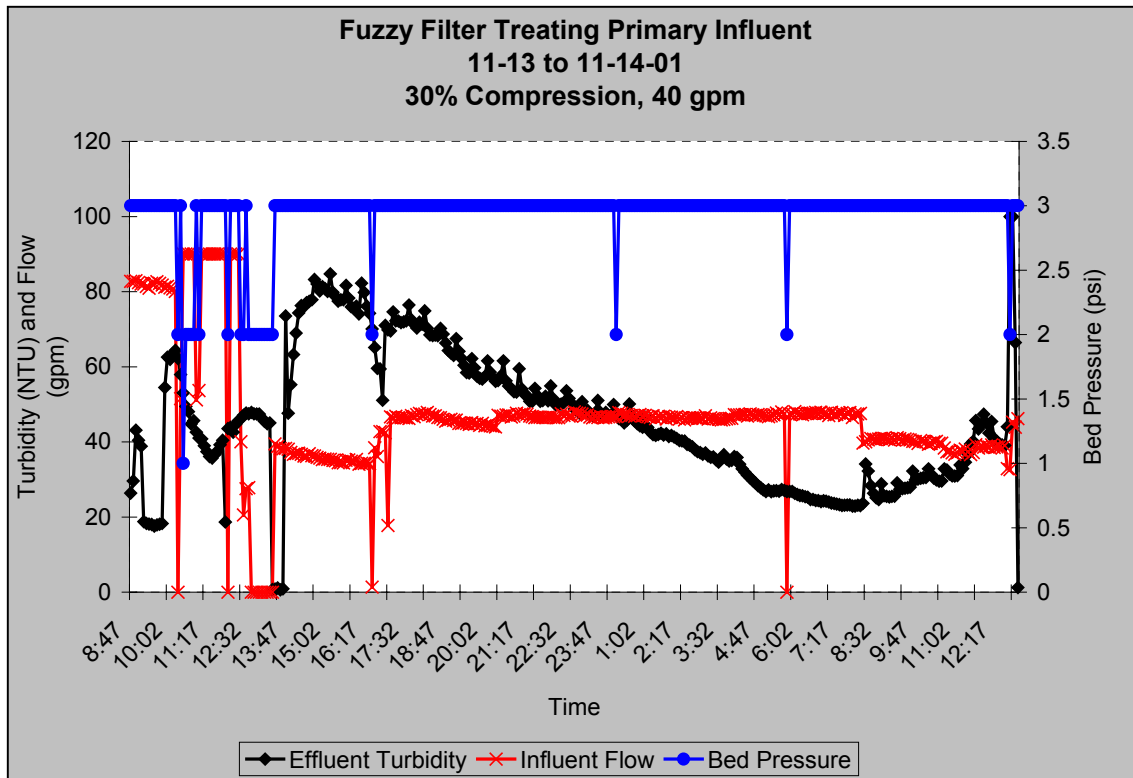


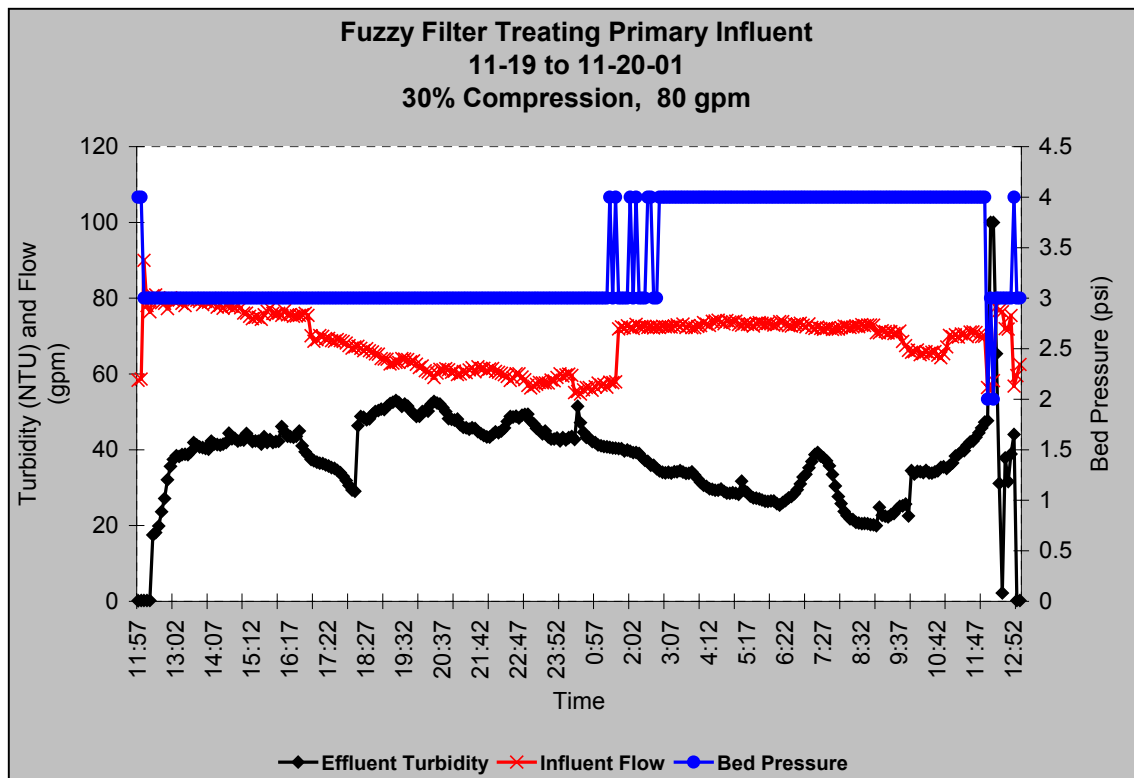
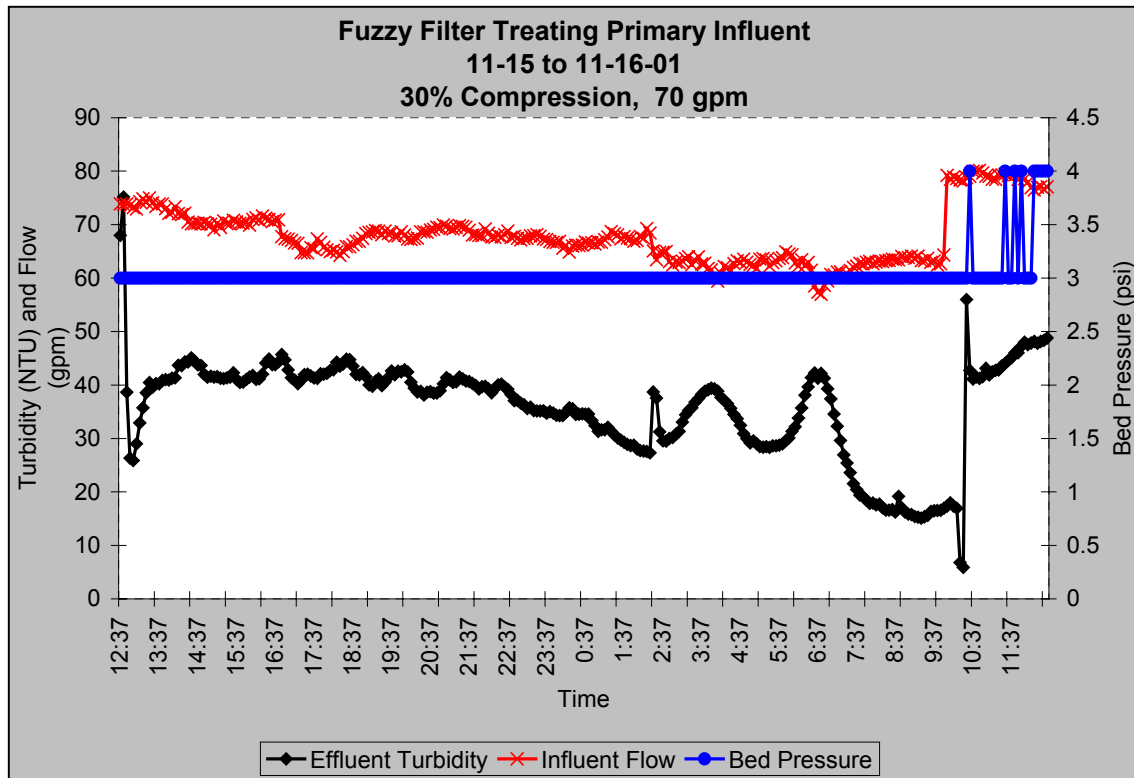


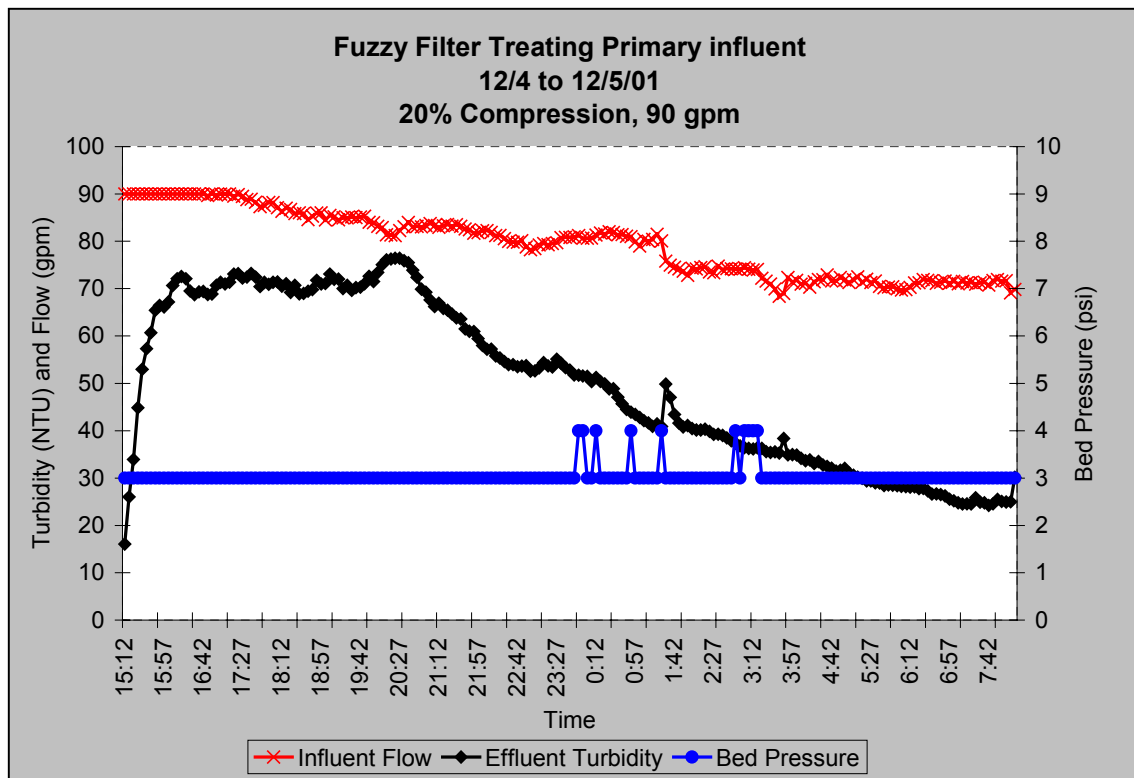
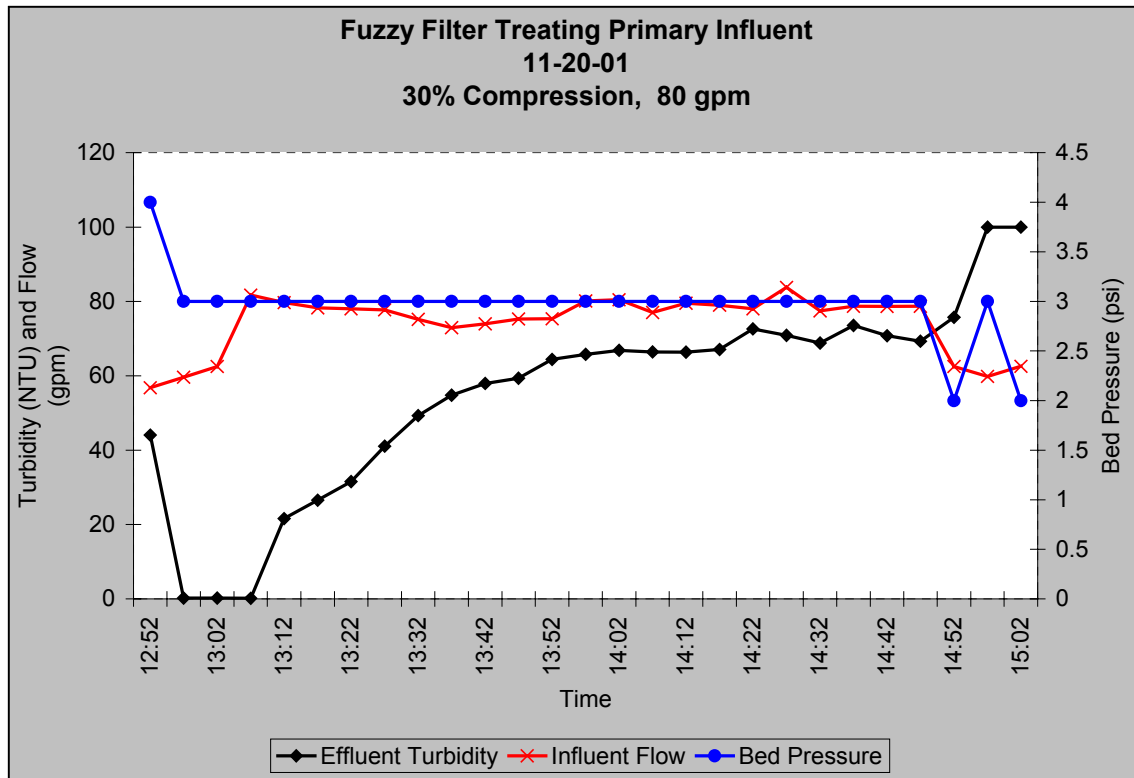






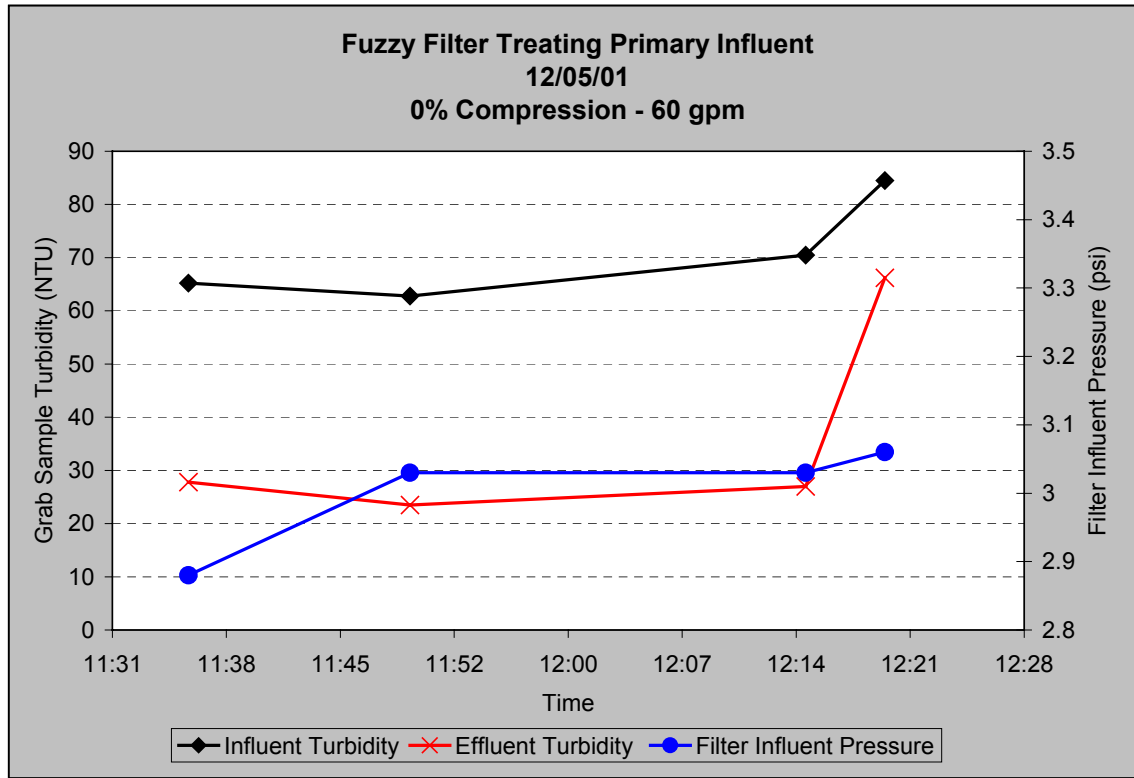




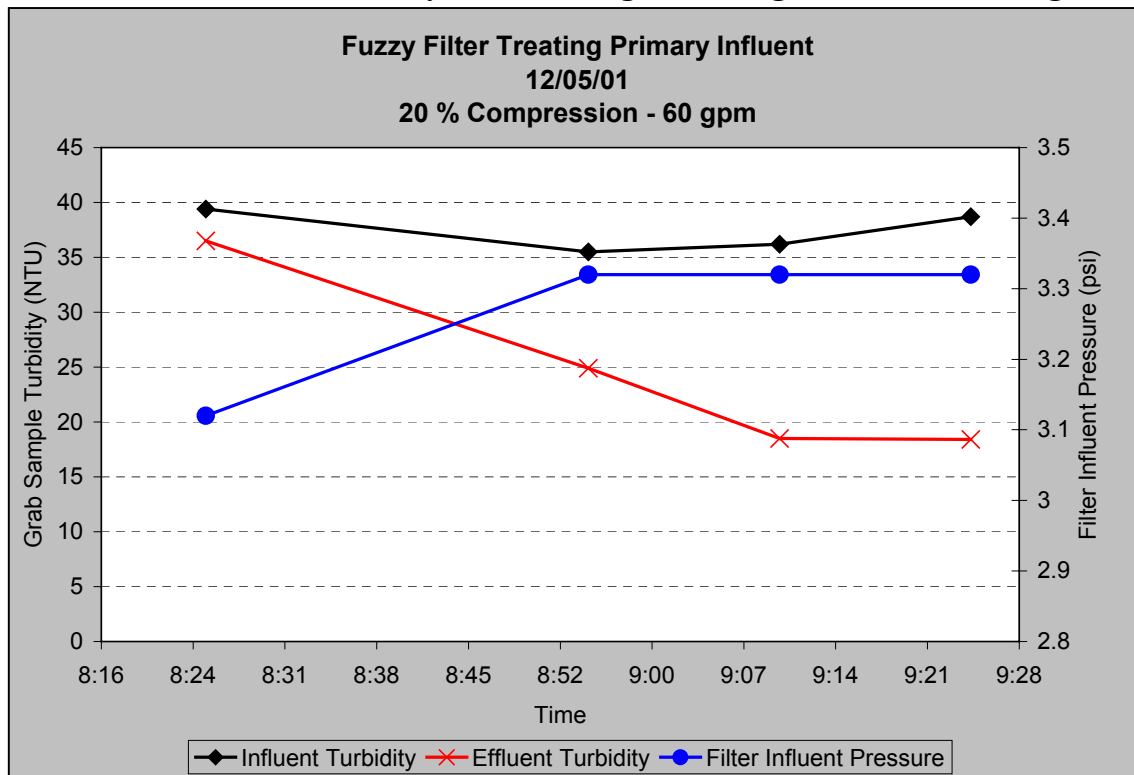




Short-Term Fuzzy Filter Testing to Investigate Short-Circuiting

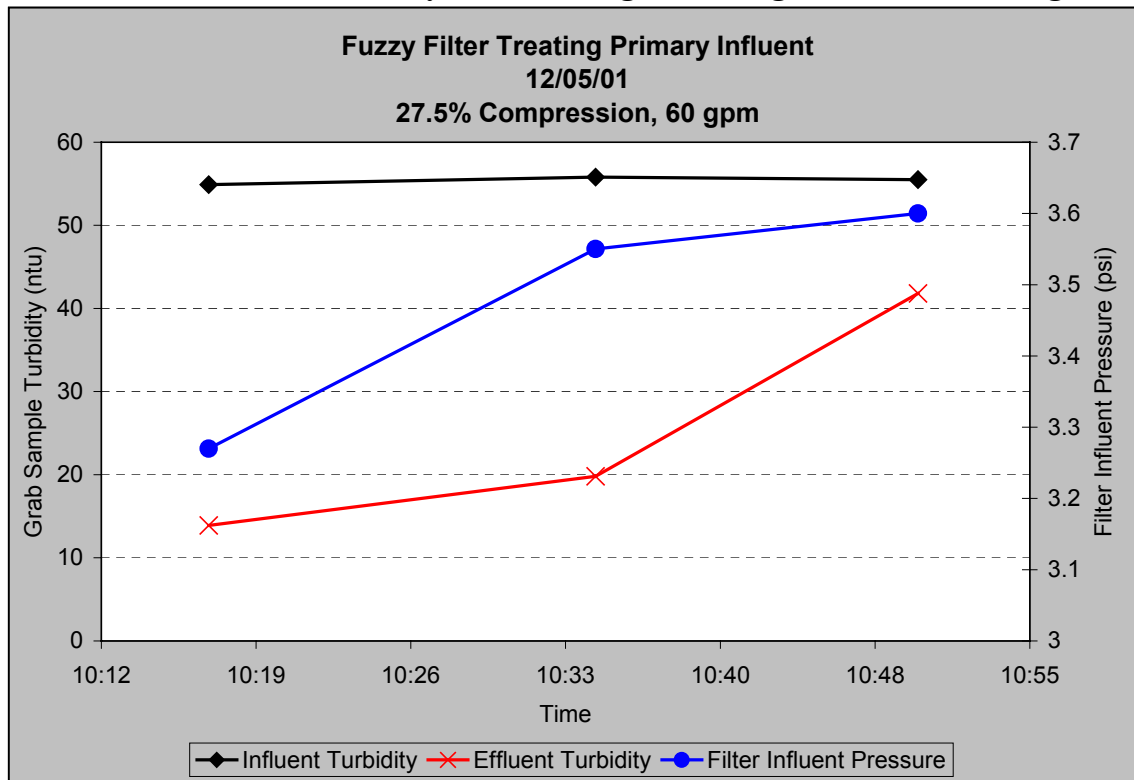


Short-Term Fuzzy Filter Testing to Investigate Short-Circuiting



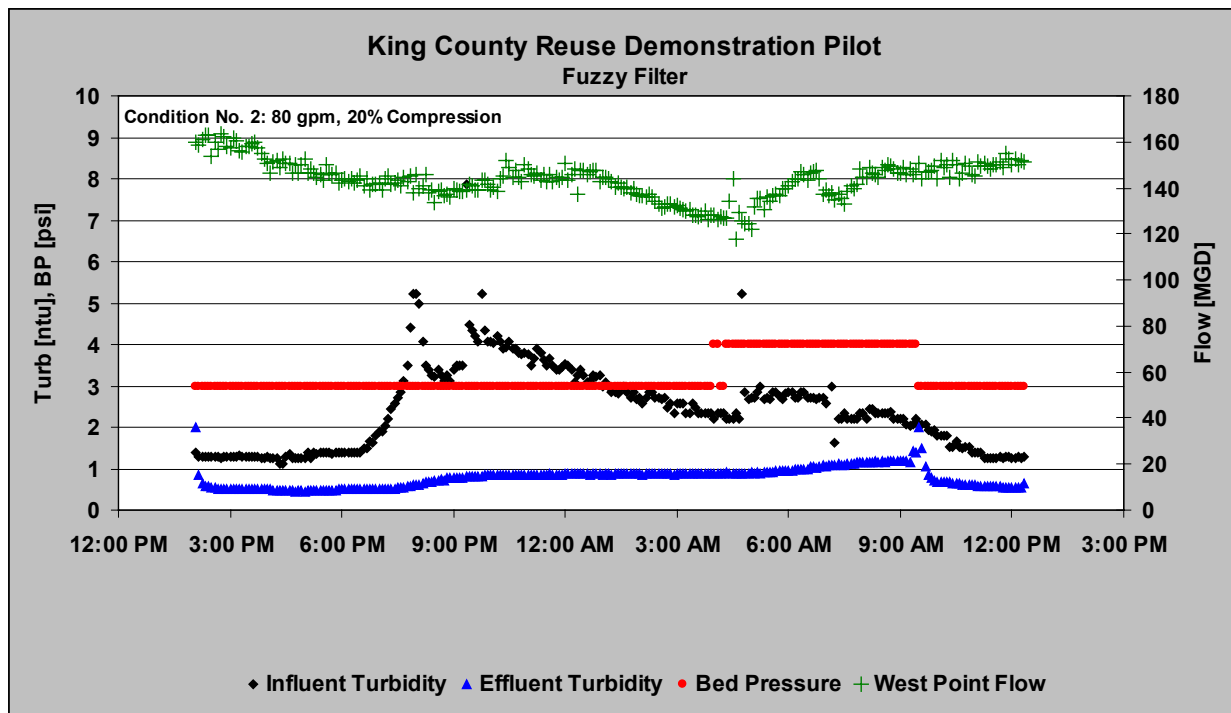
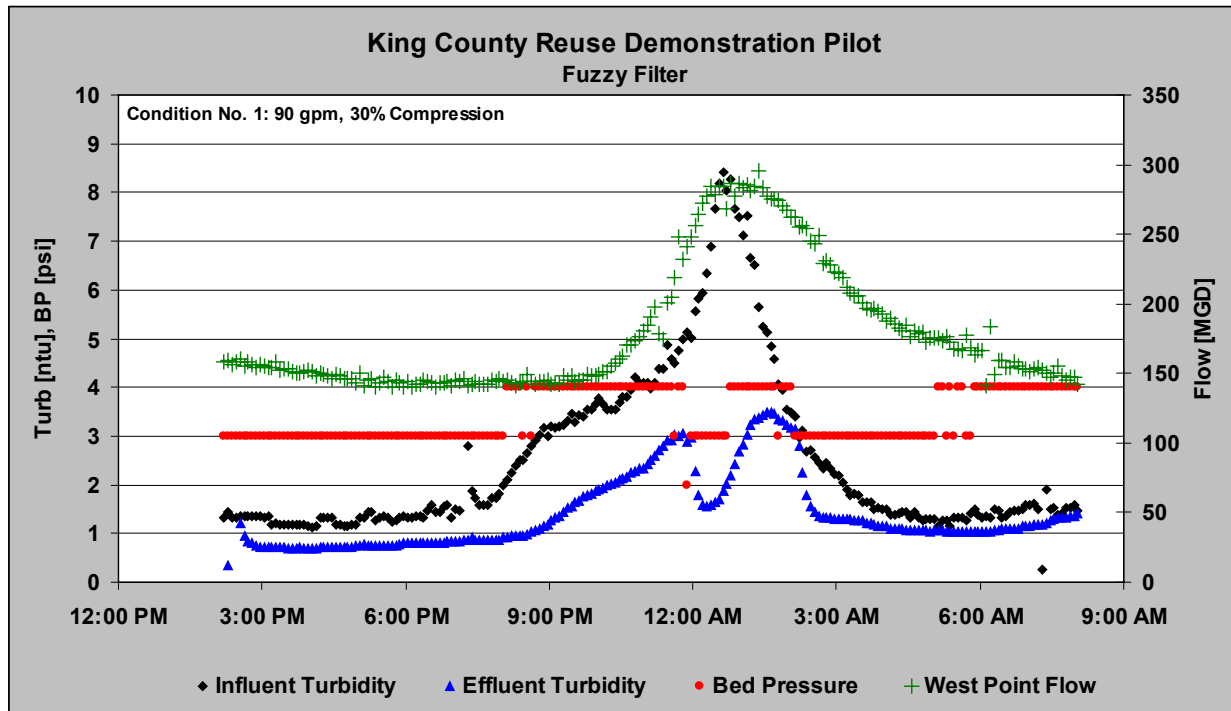


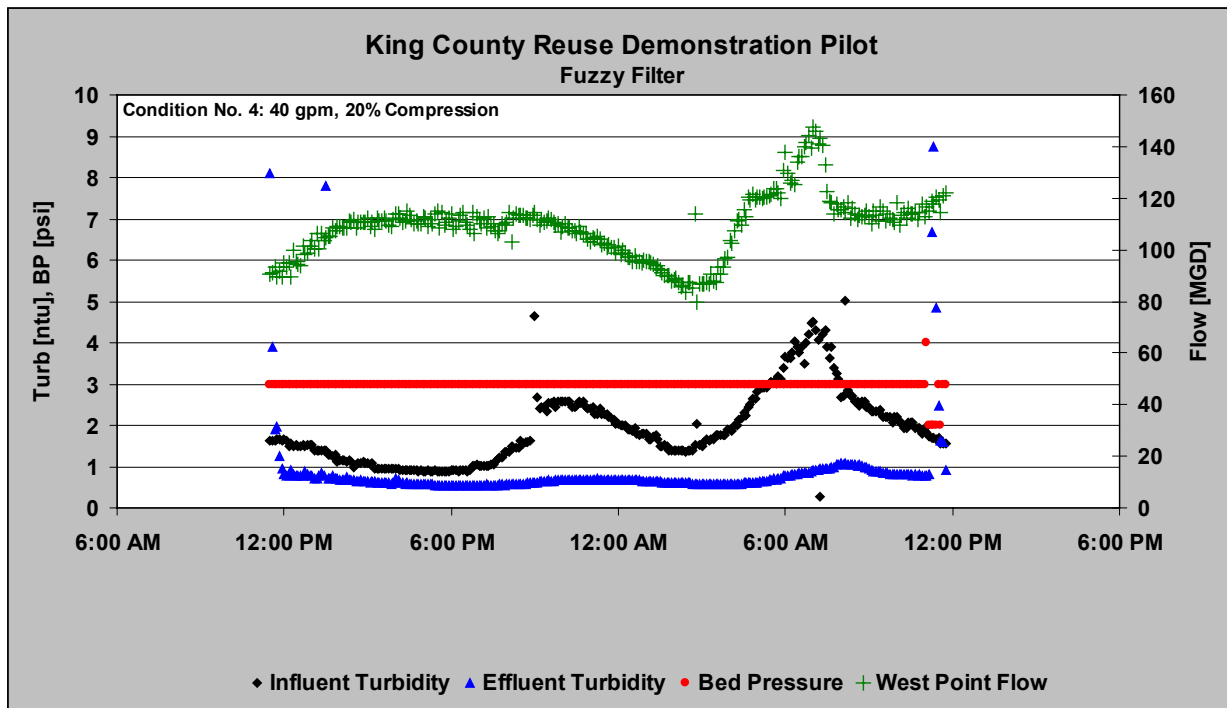
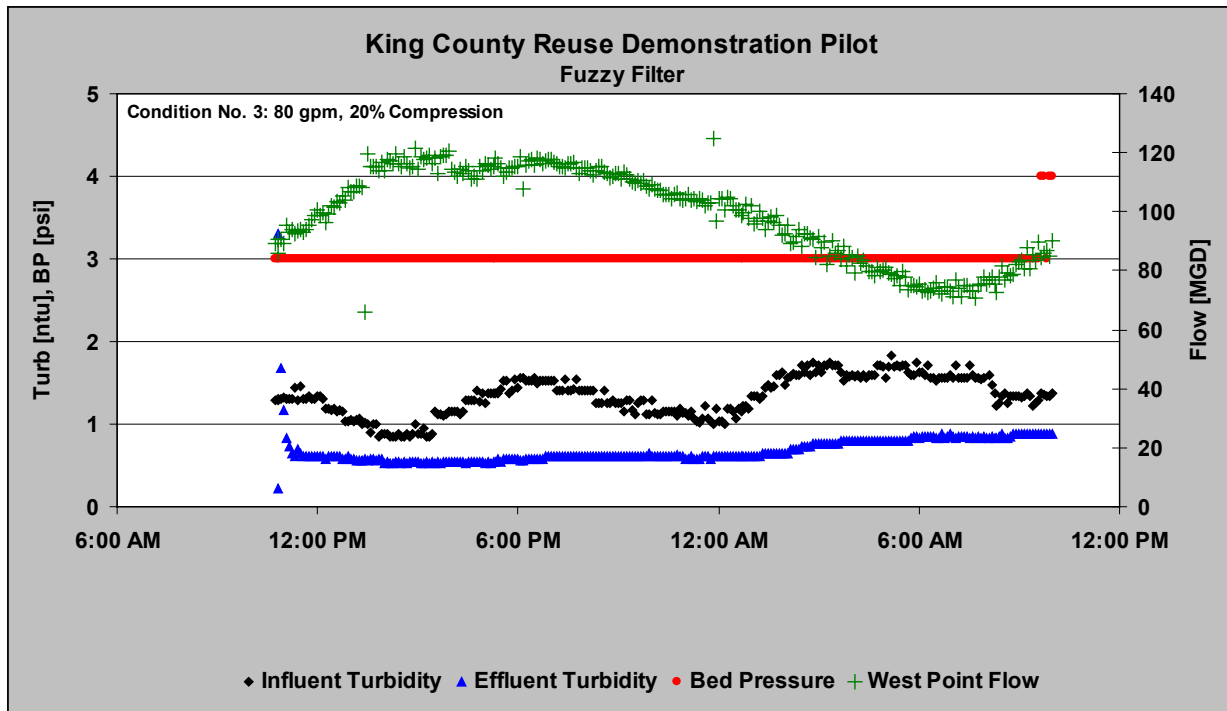
Short-Term Fuzzy Filter Testing to Investigate Short-Circuiting

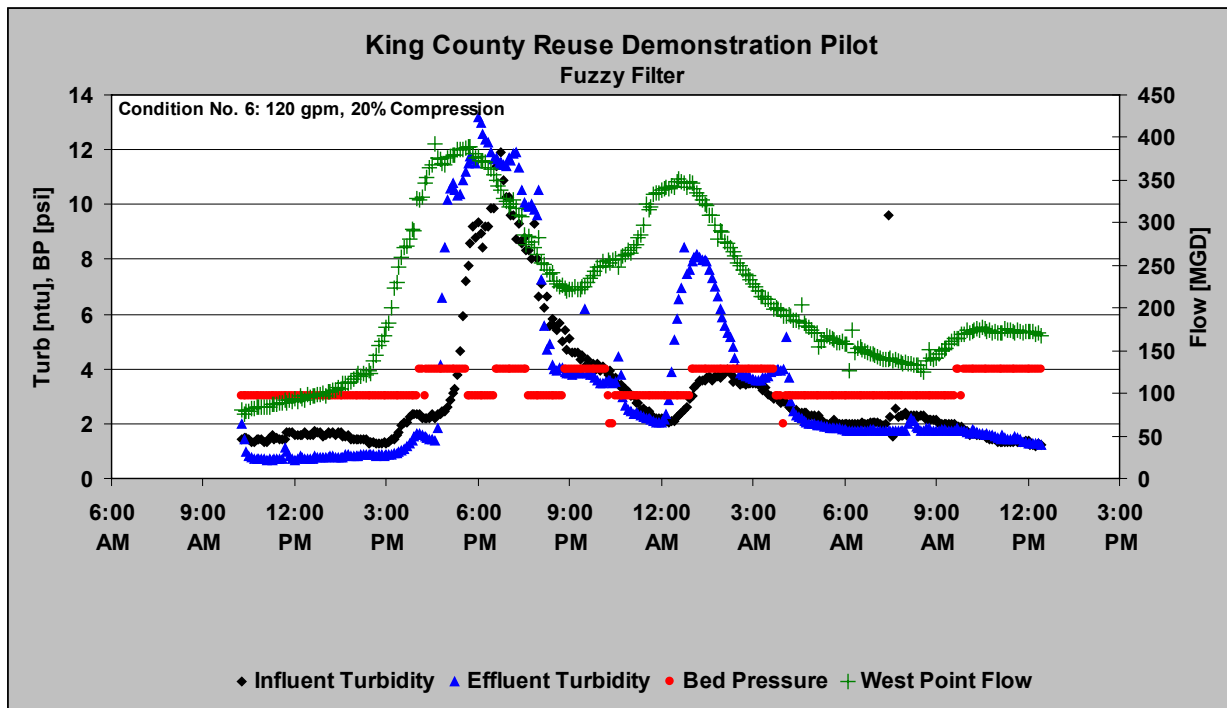
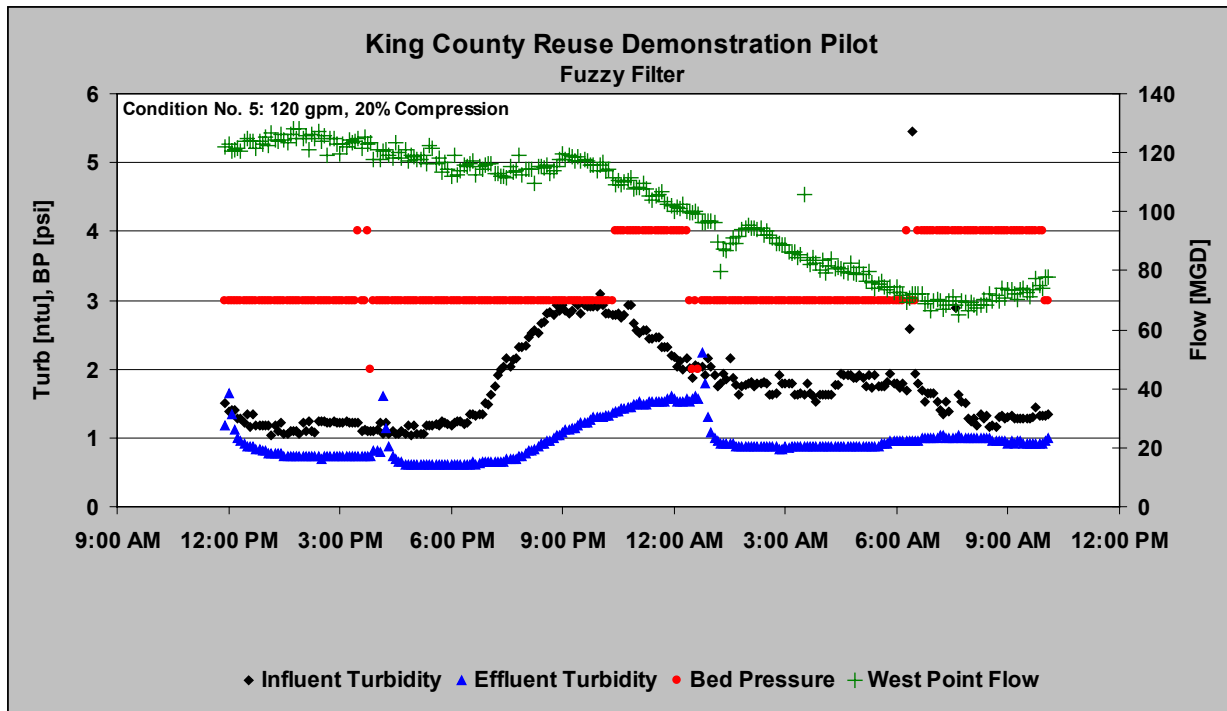


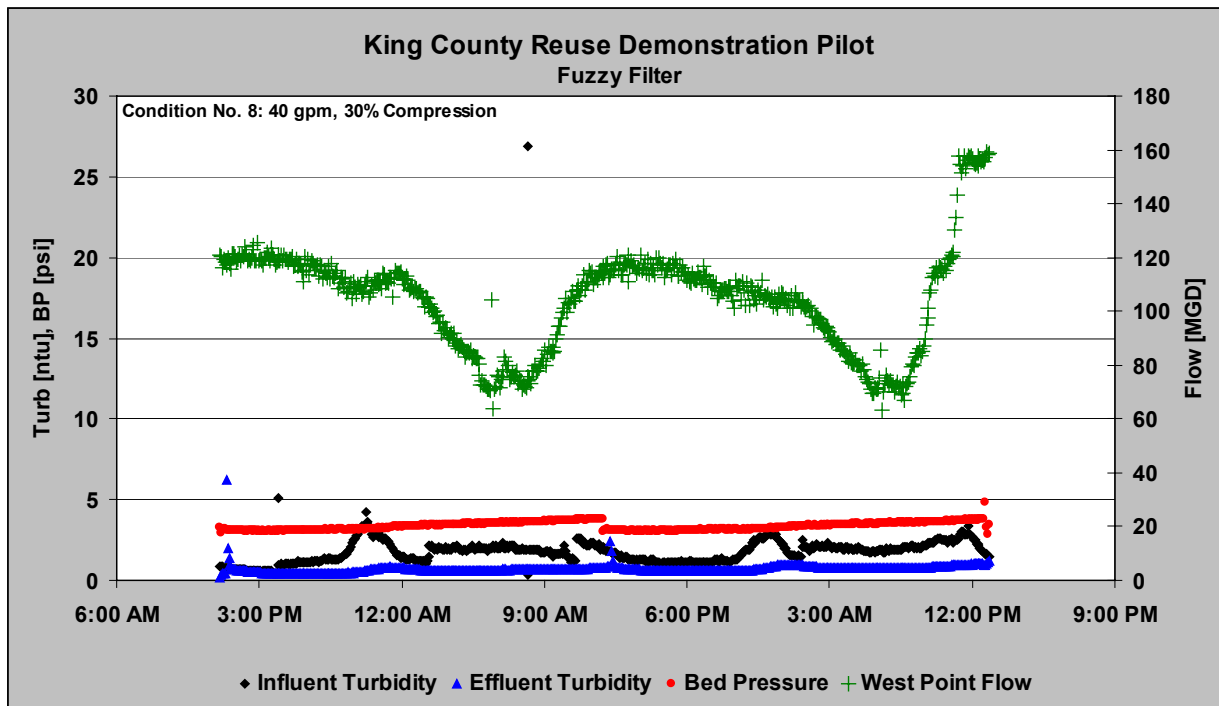
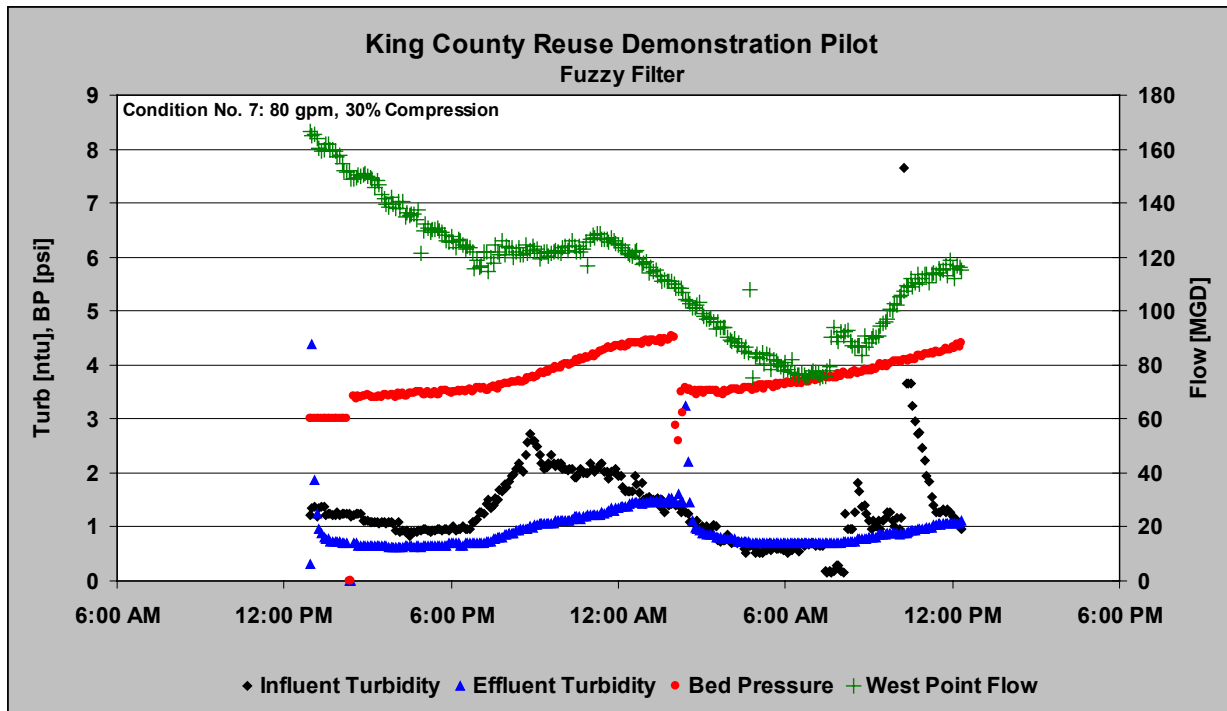


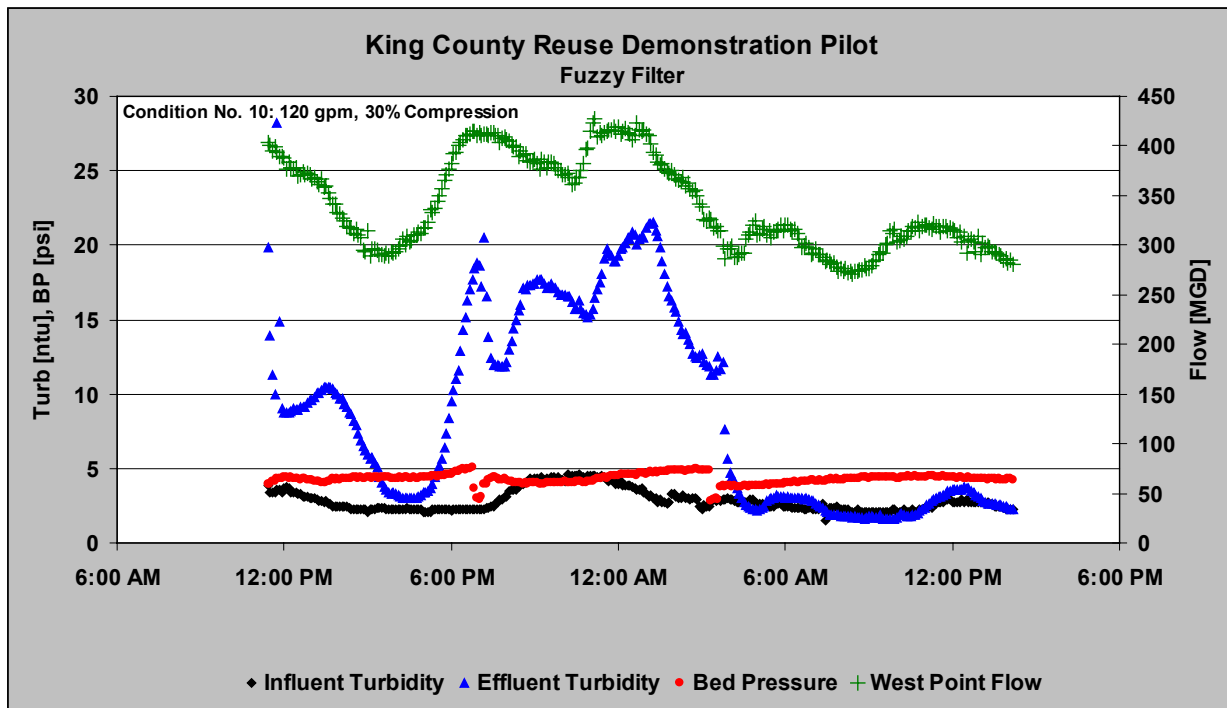
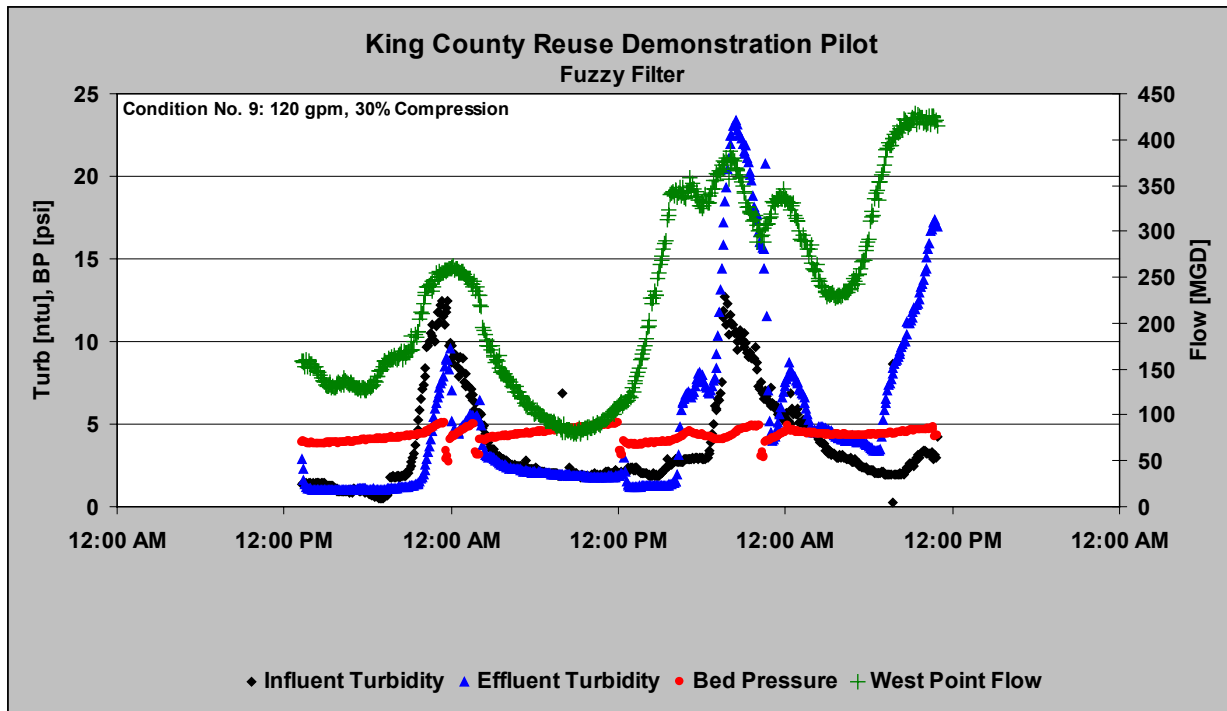
Fuzzy Filter Appendix C Graphs

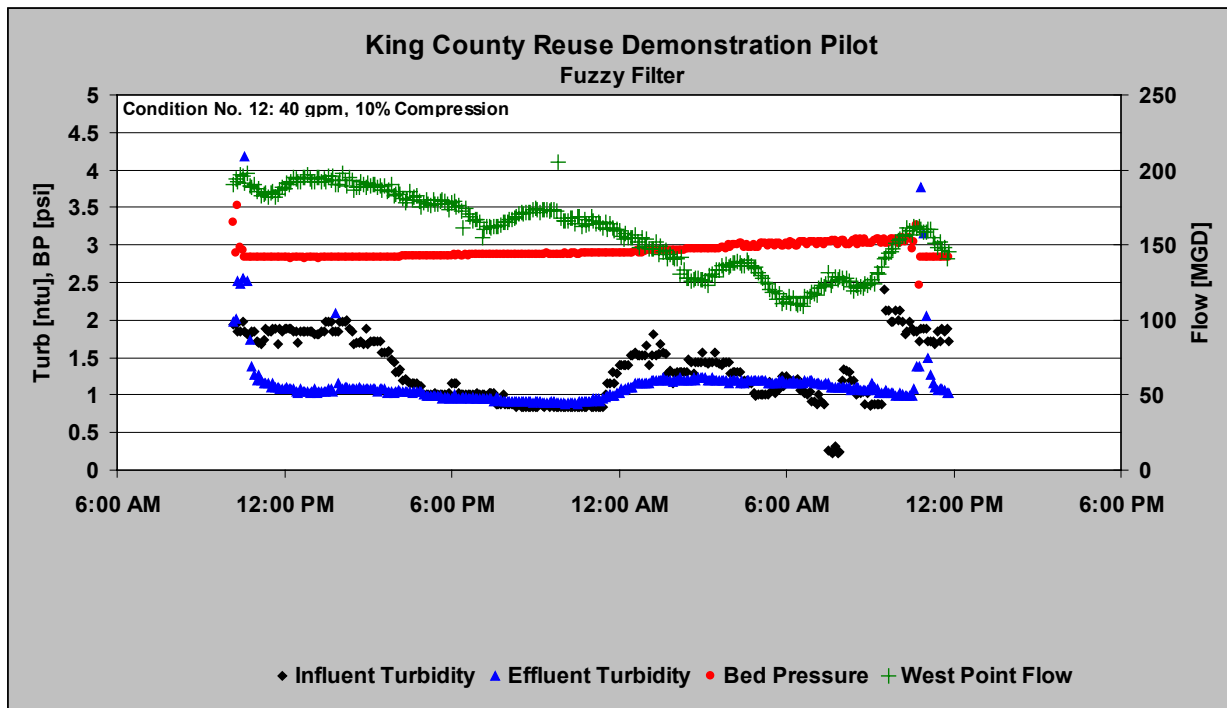
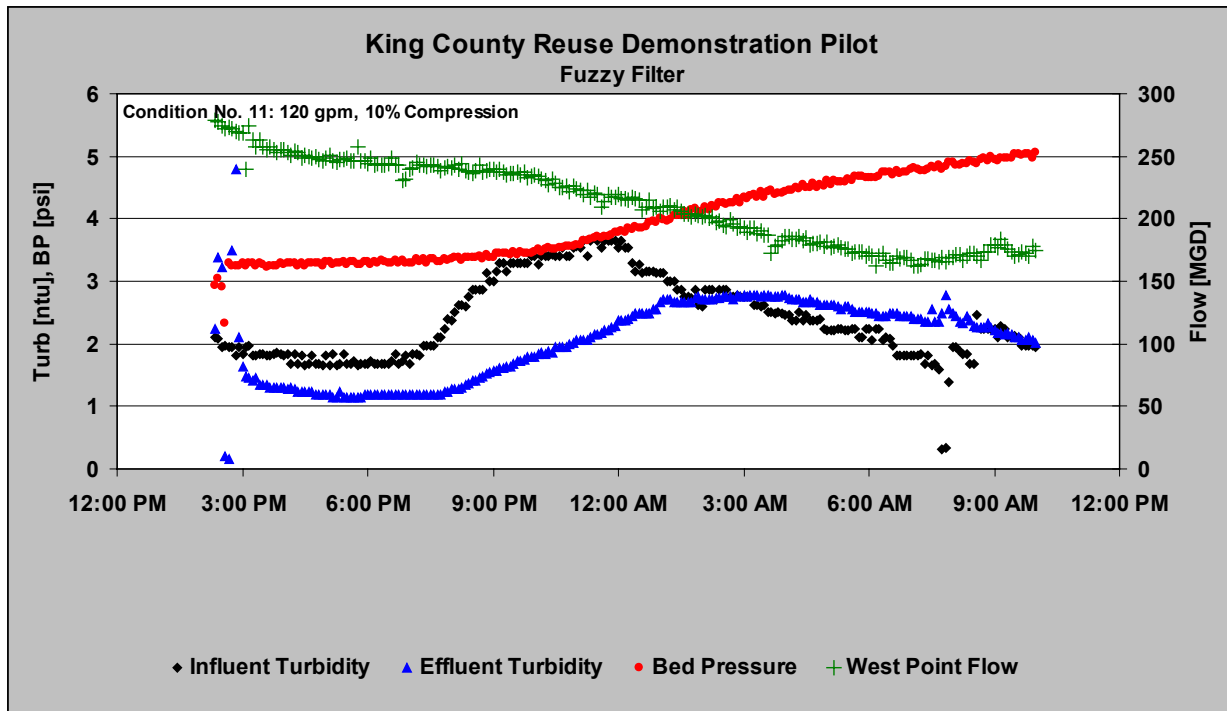


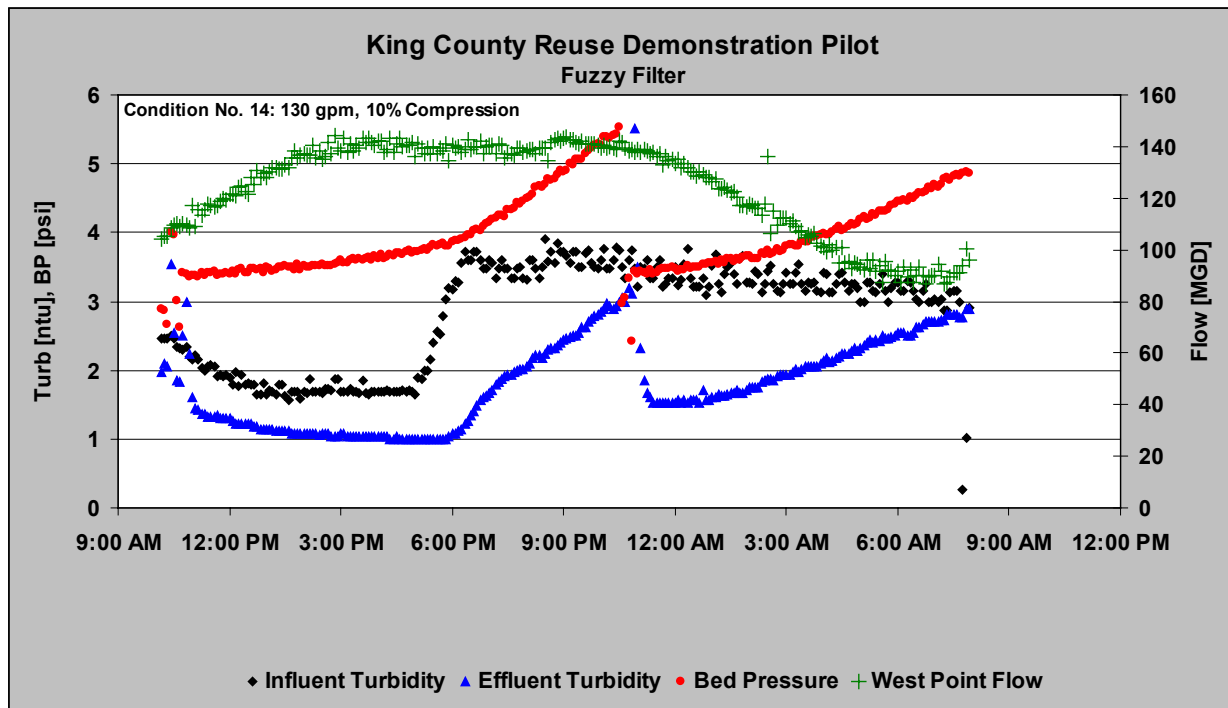
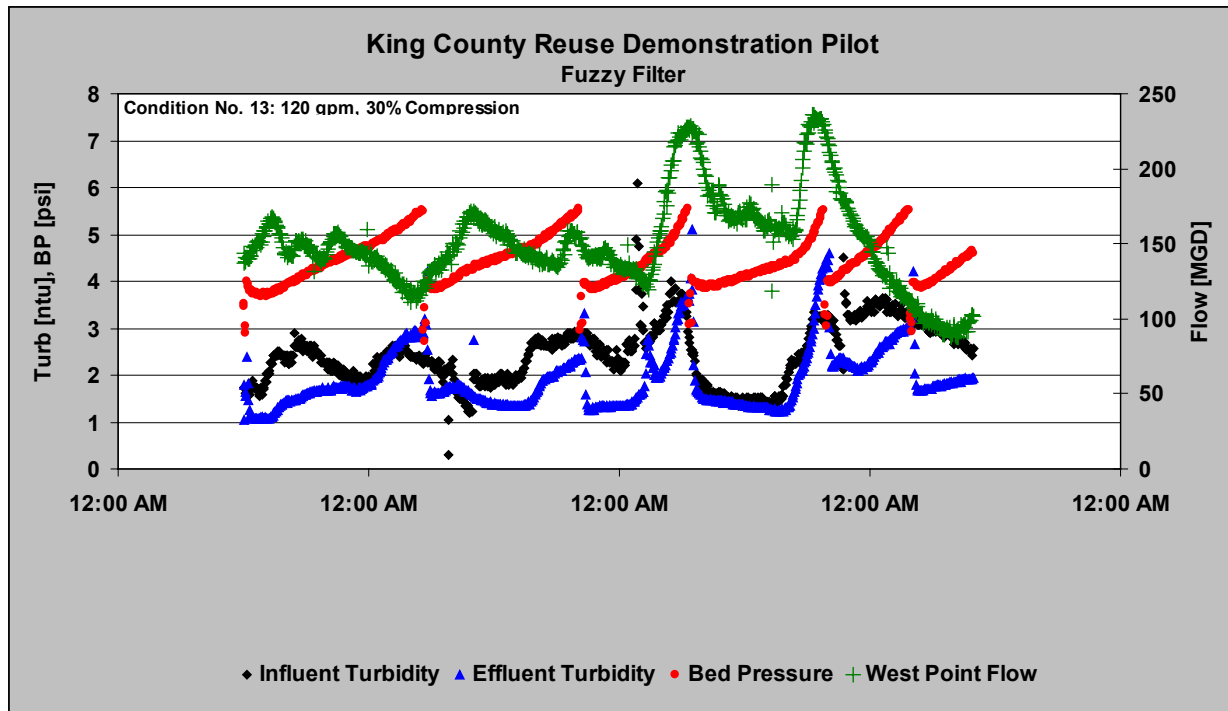


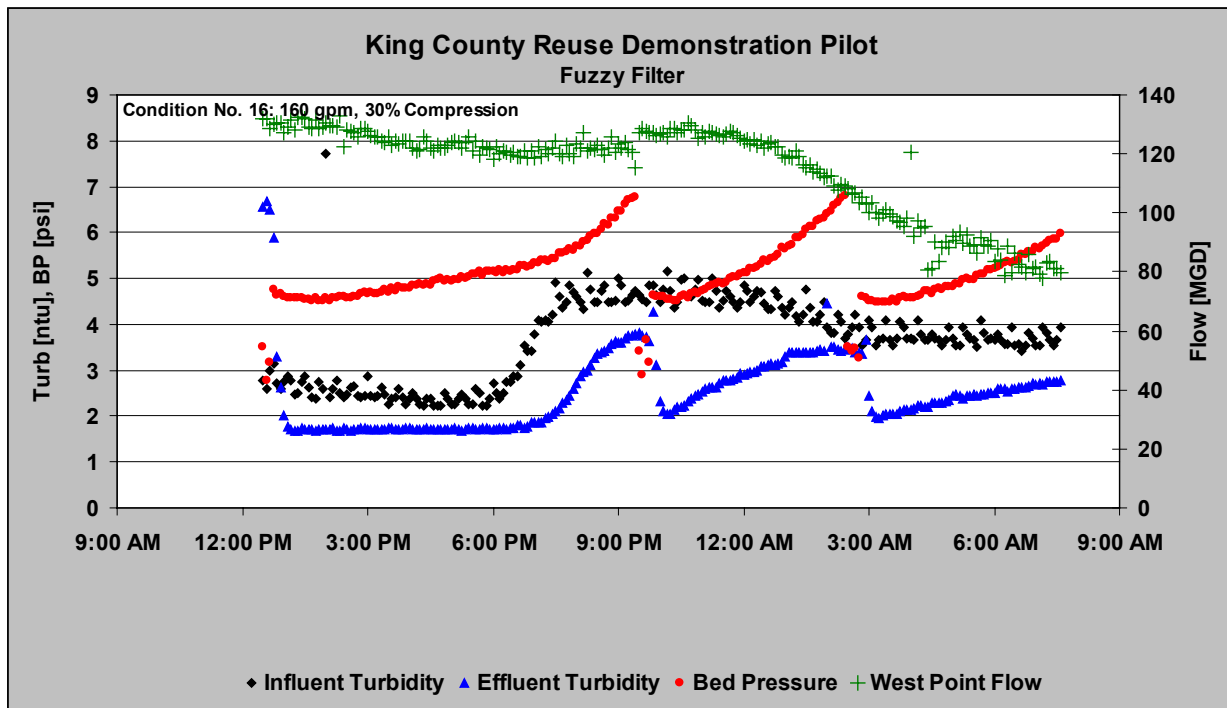
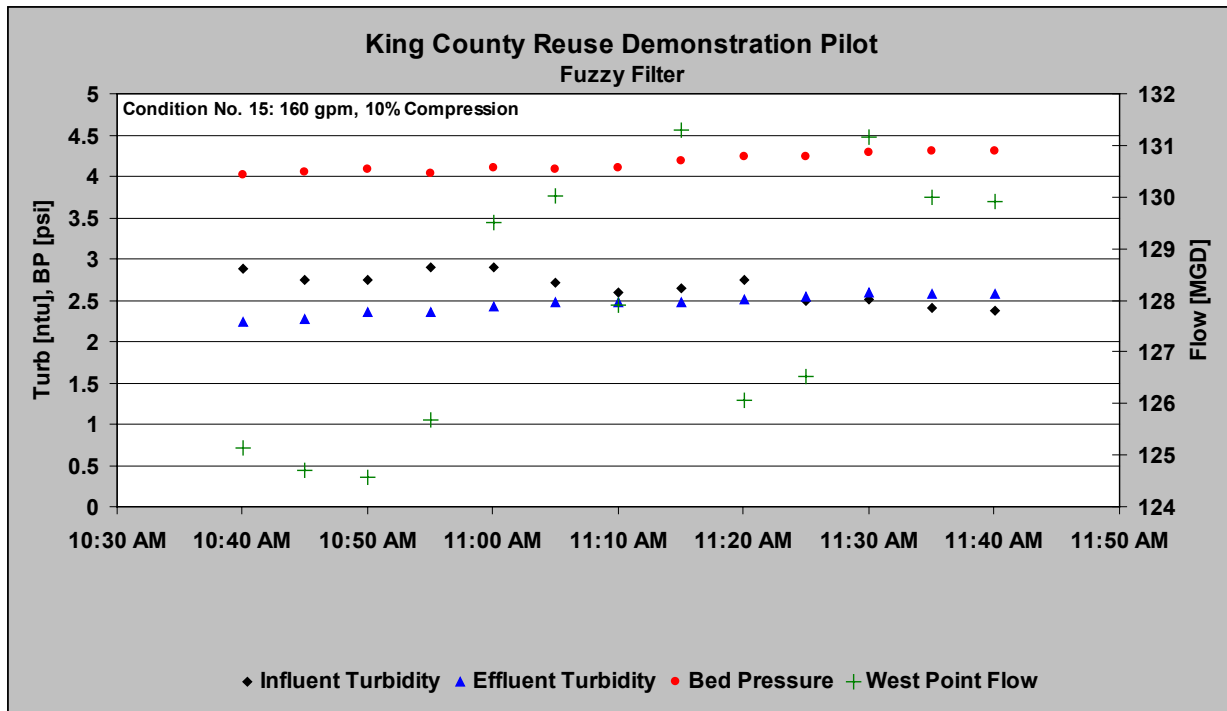


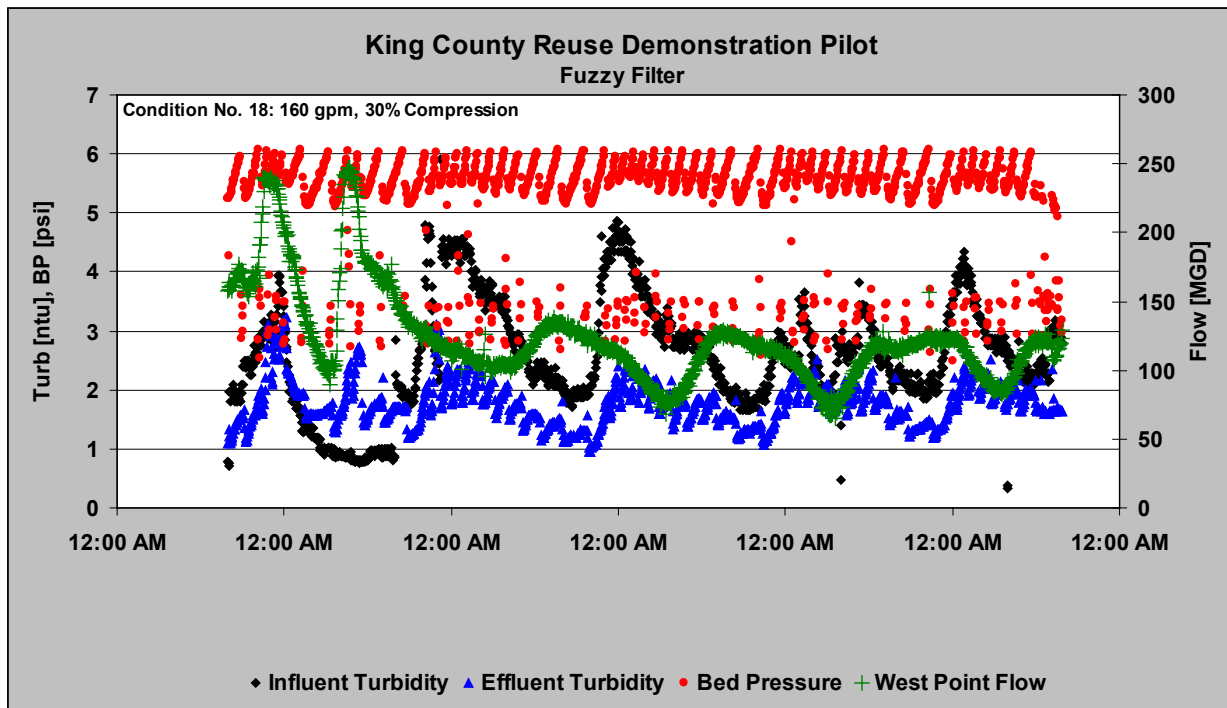
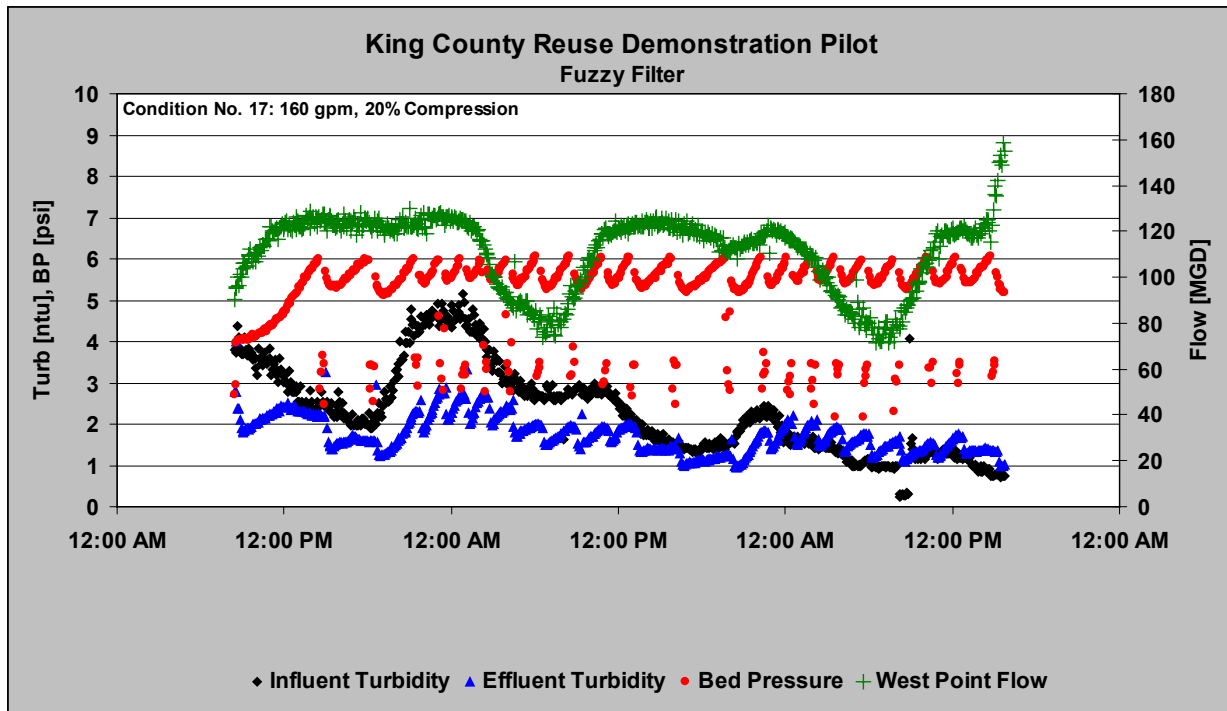


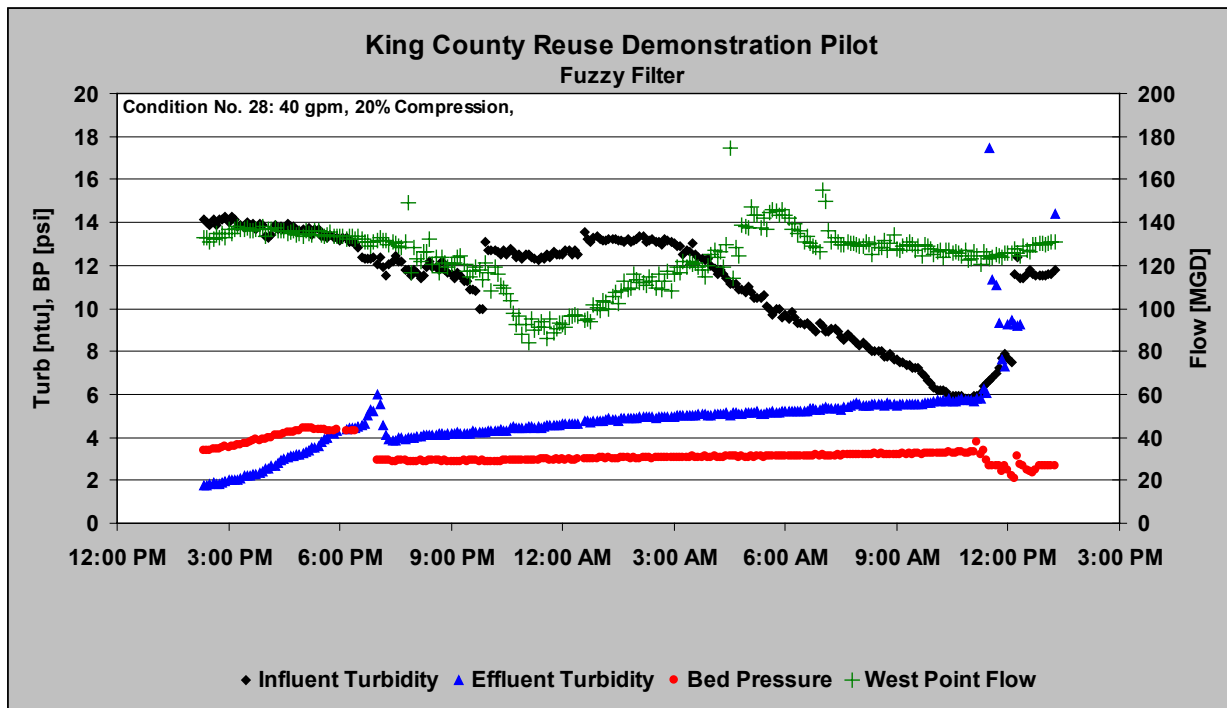
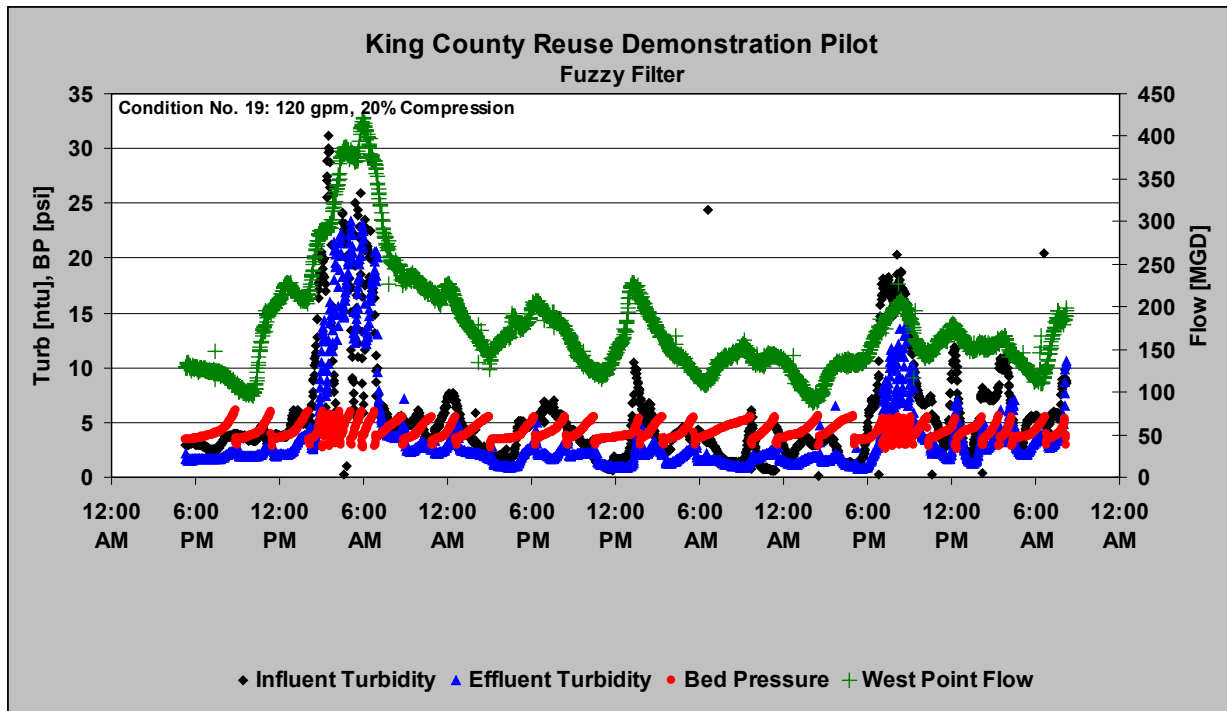


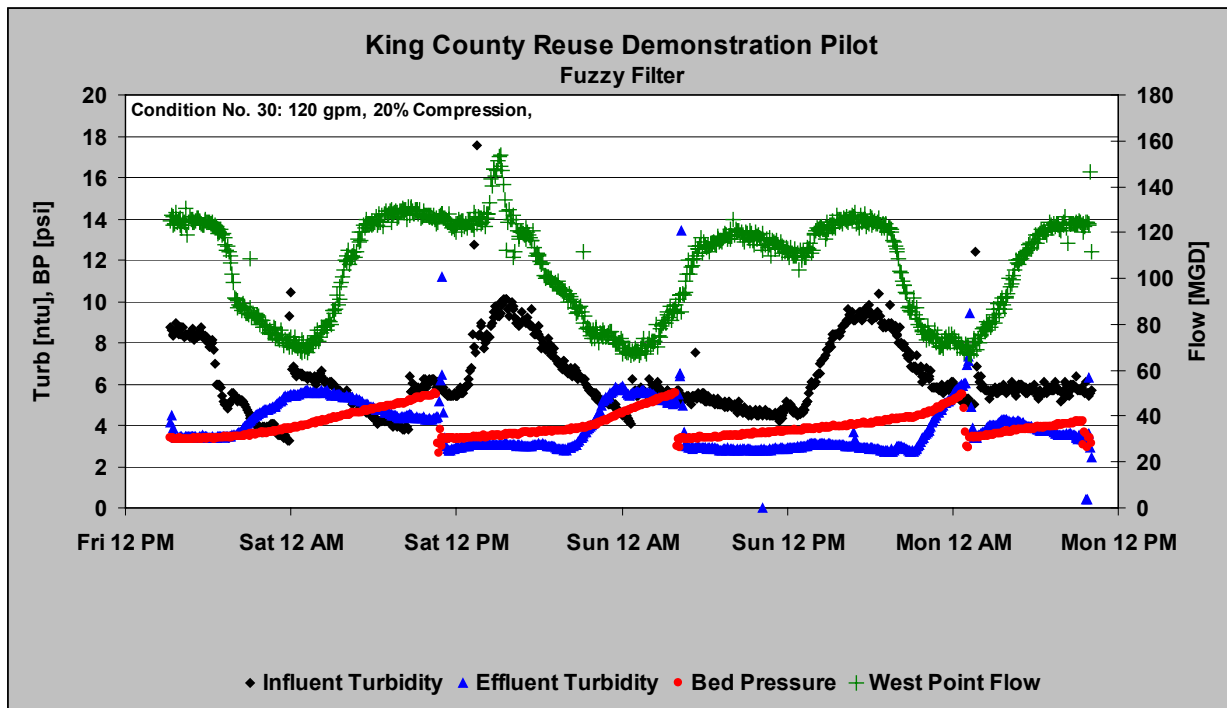
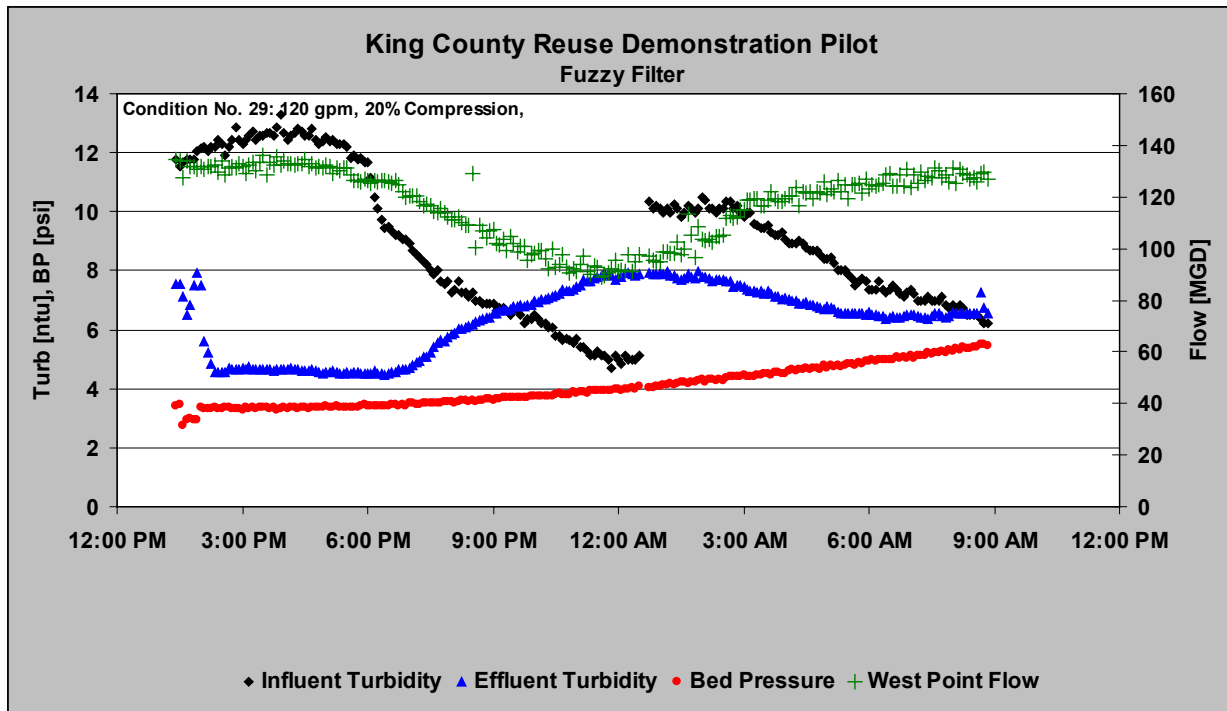


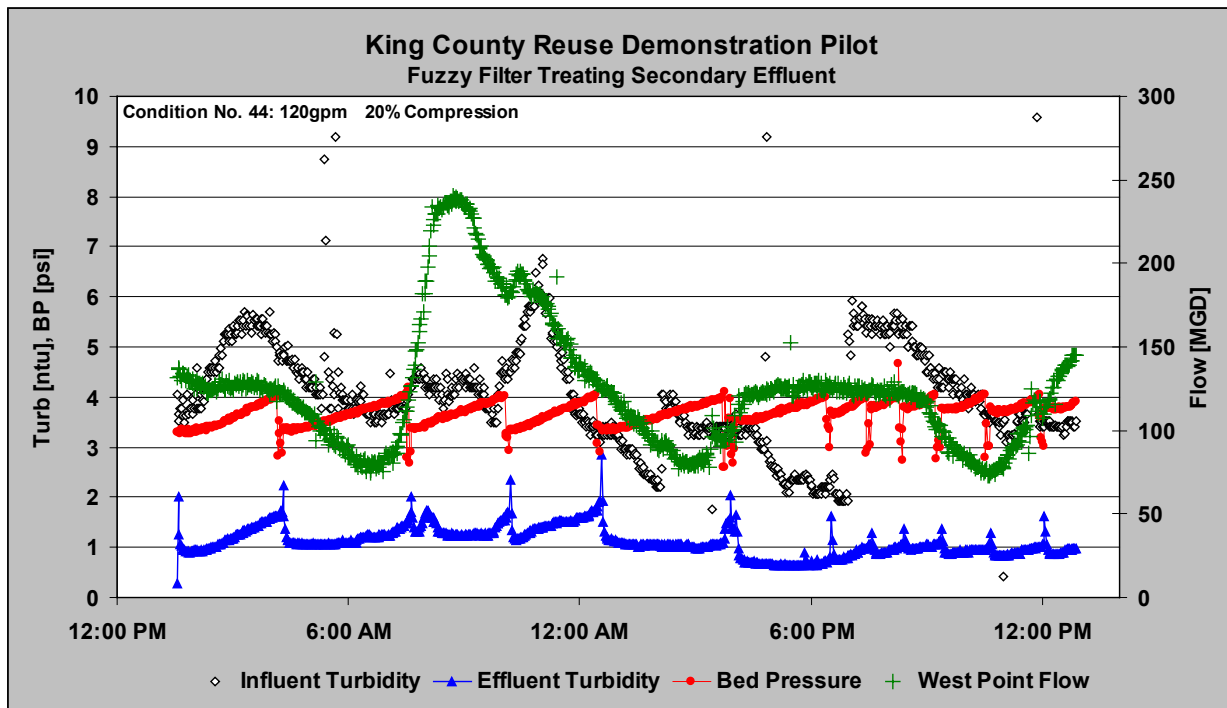
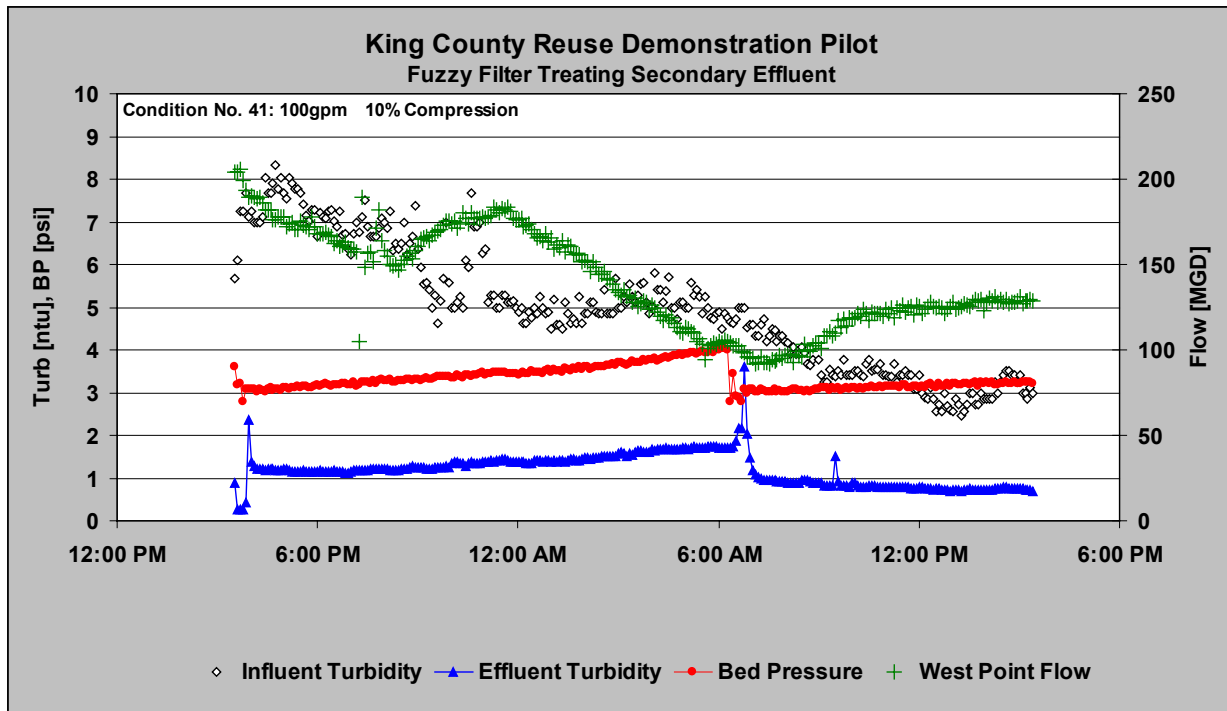






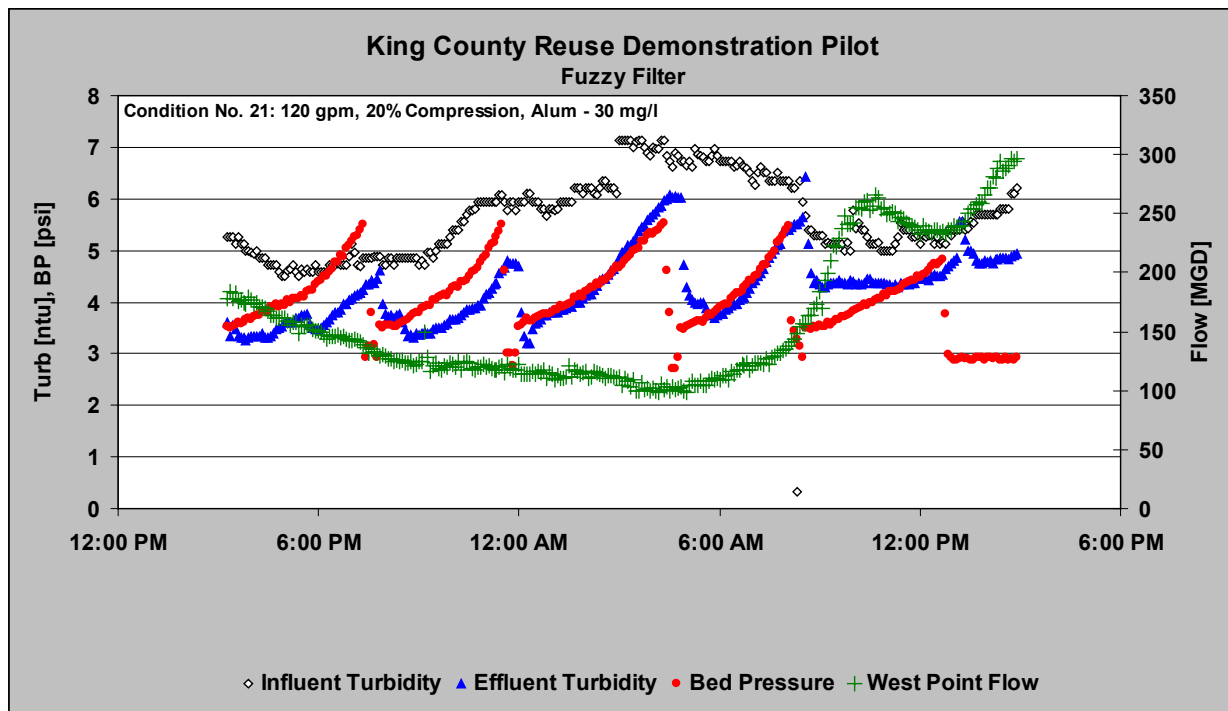
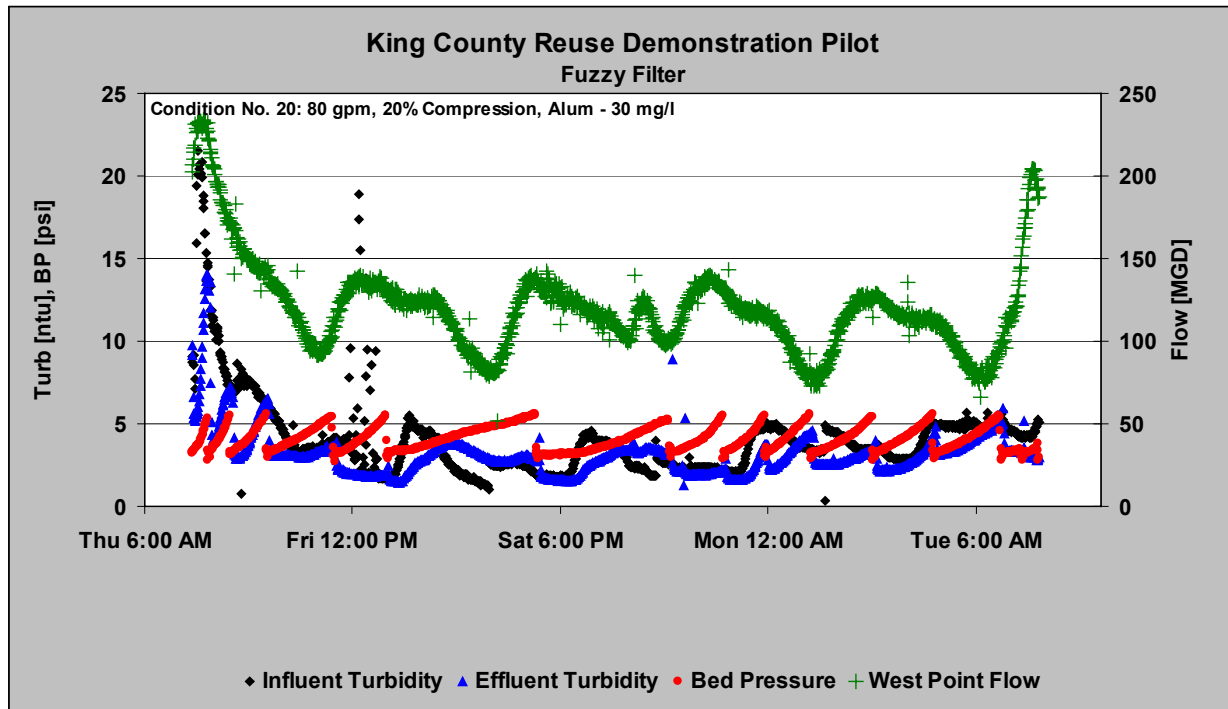


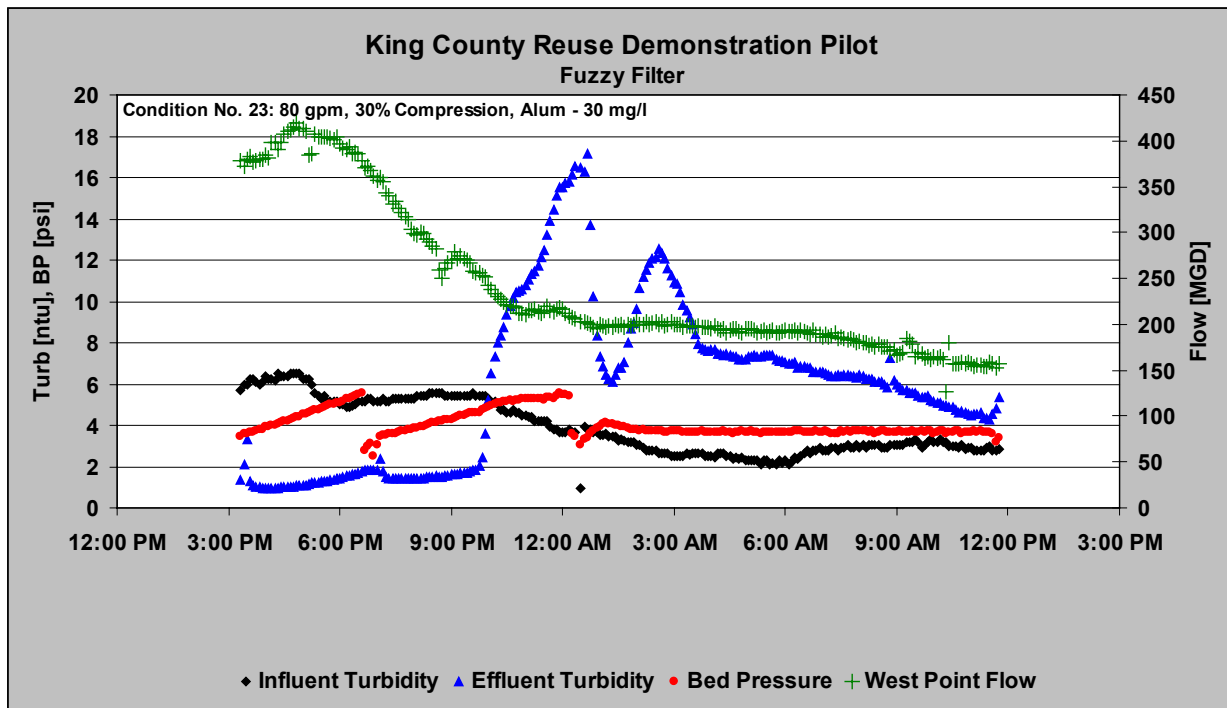
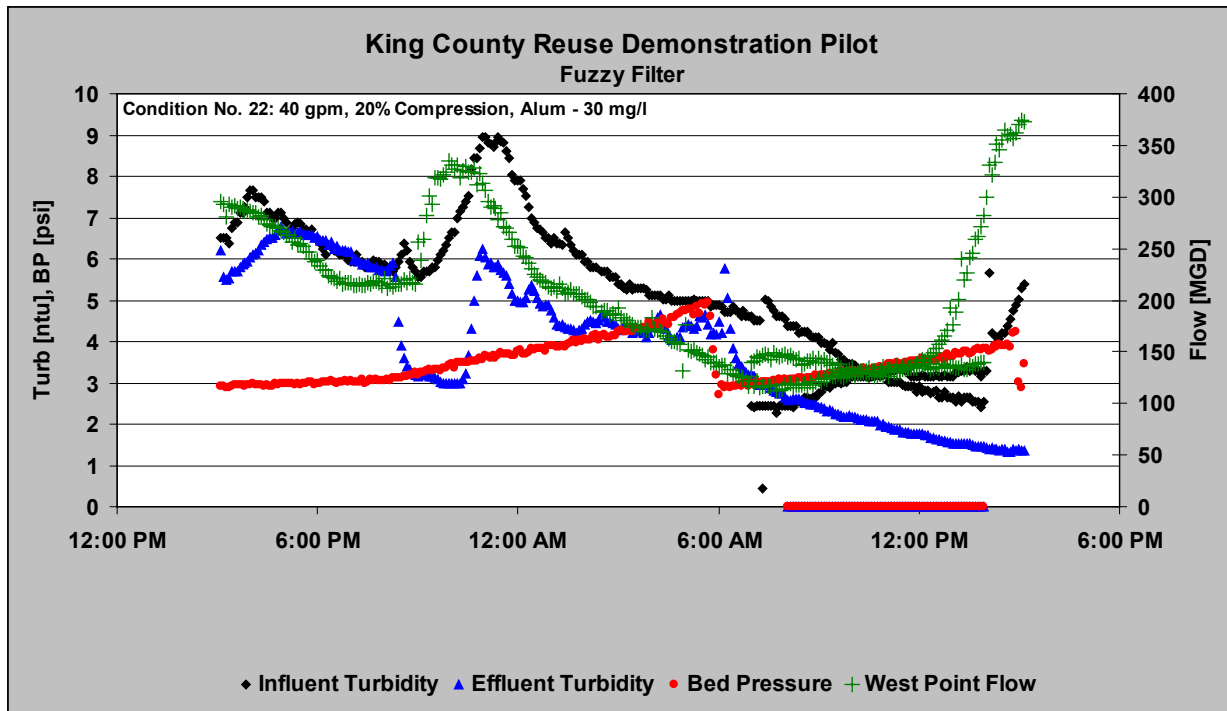


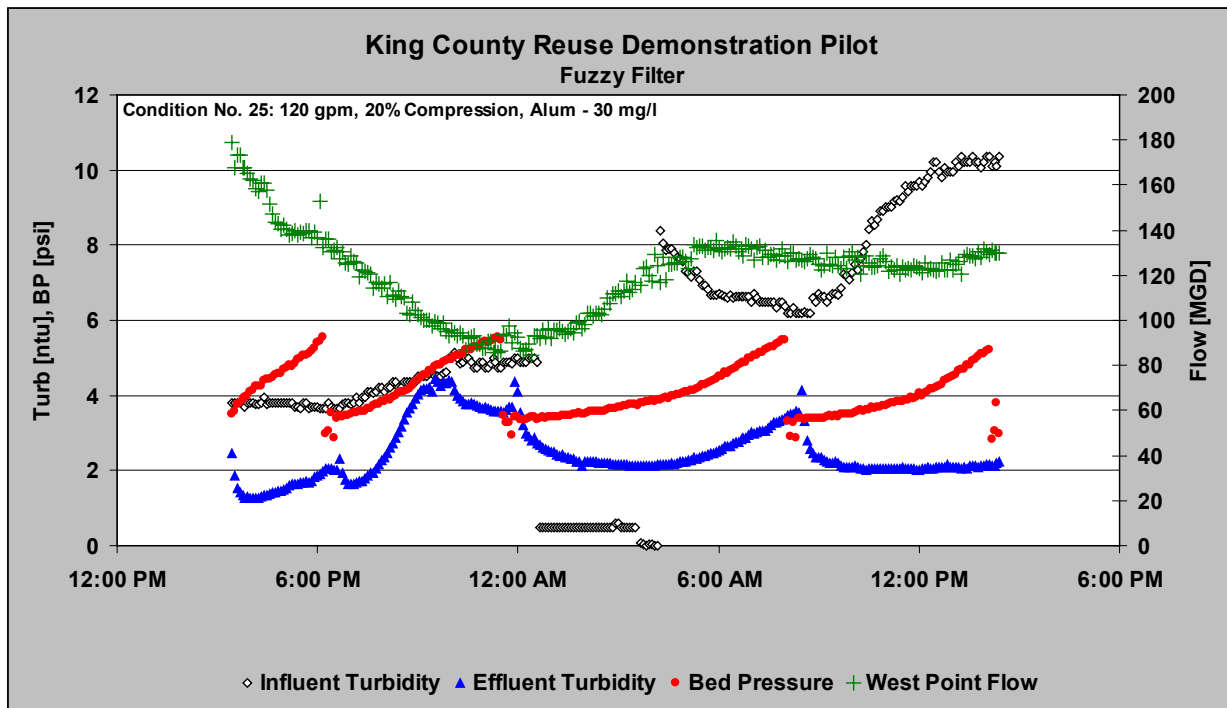
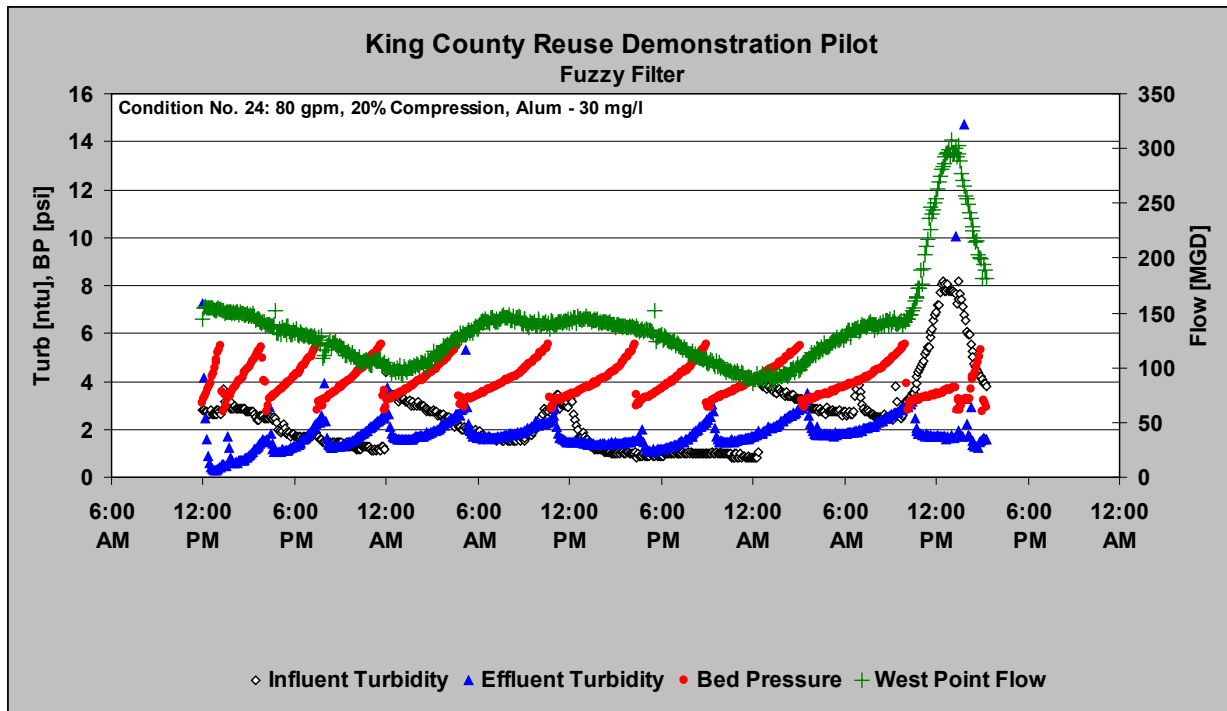


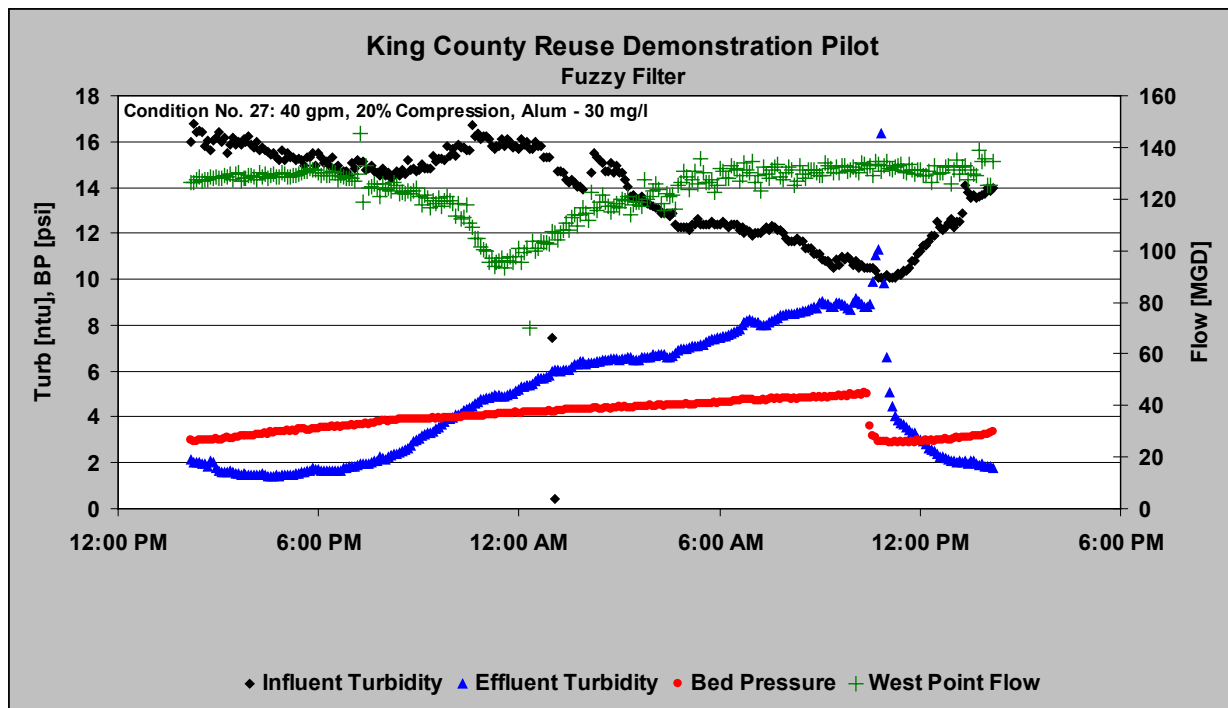
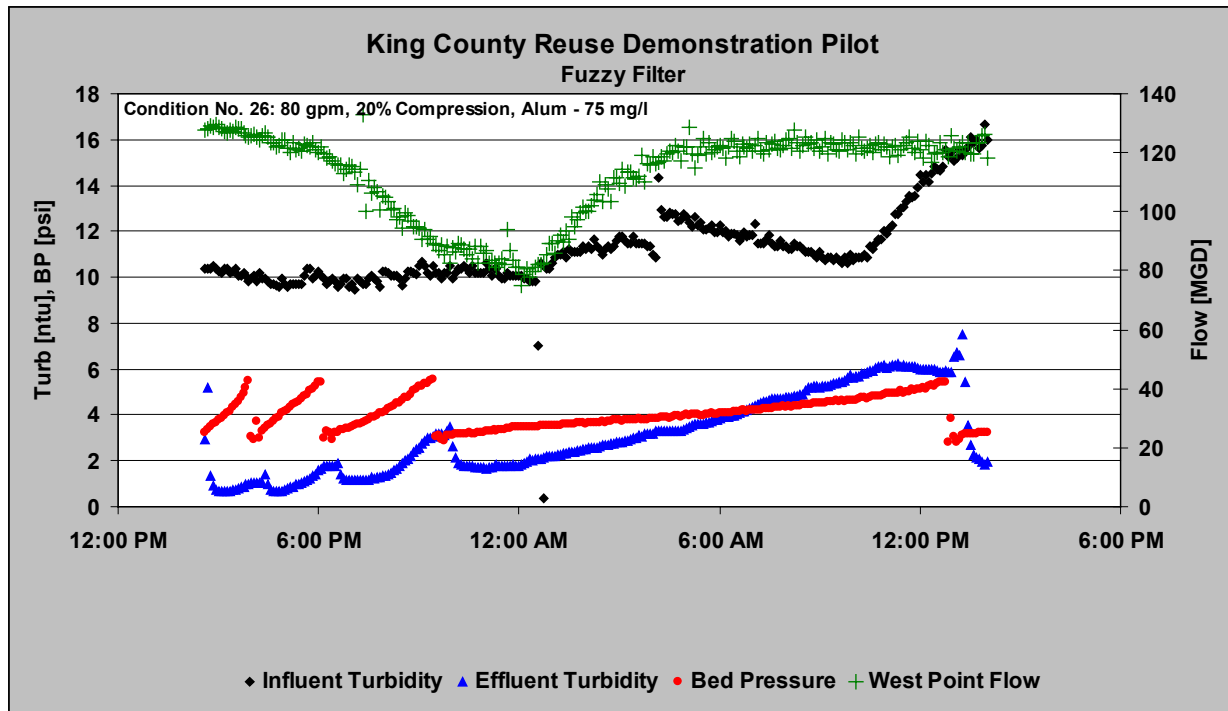


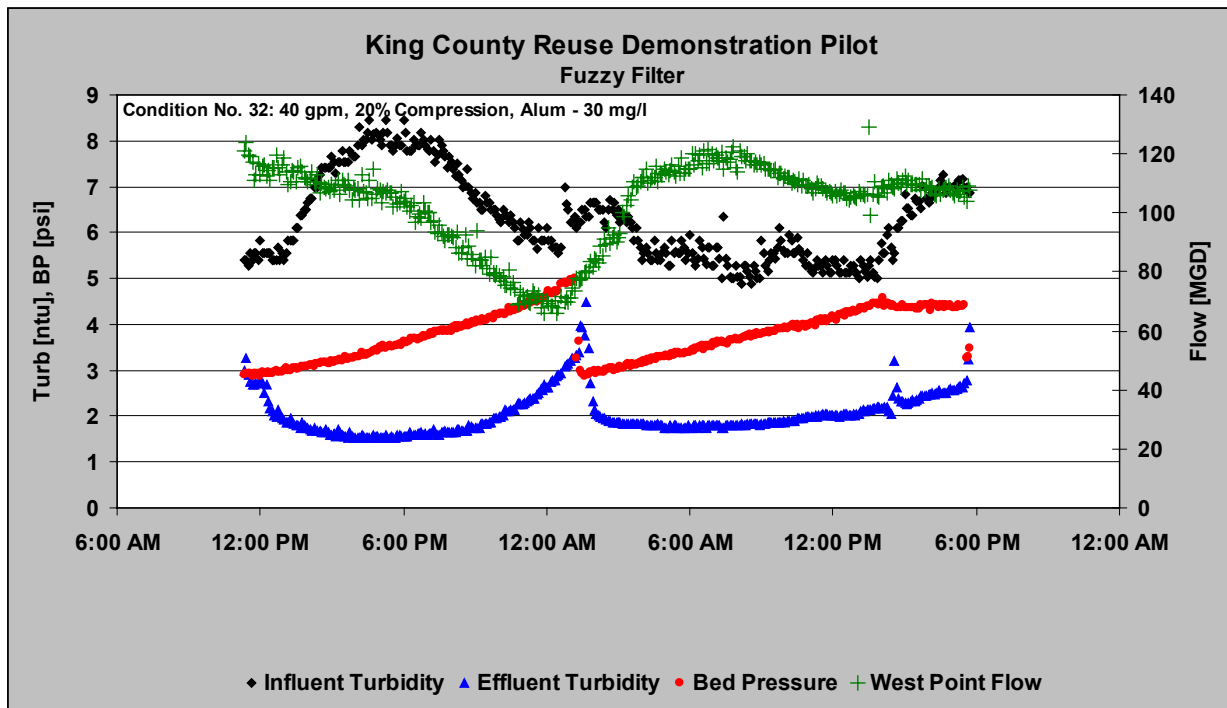
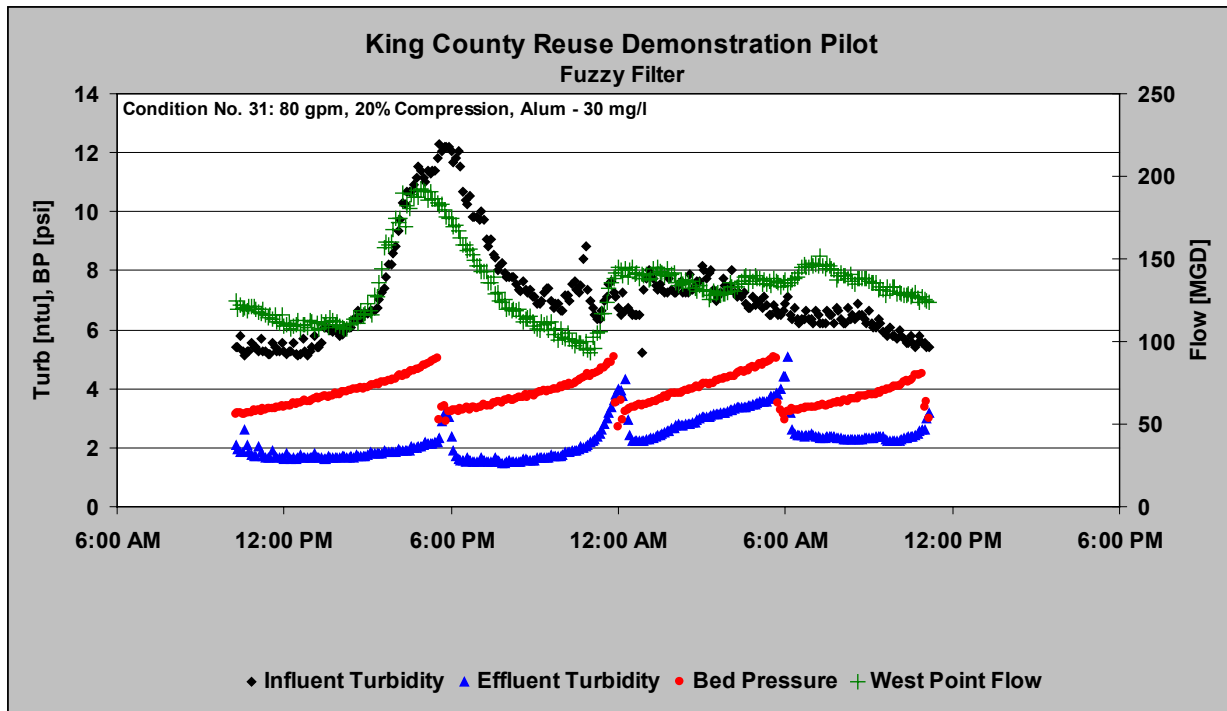
Fuzzy Filter Appendix D Graphs

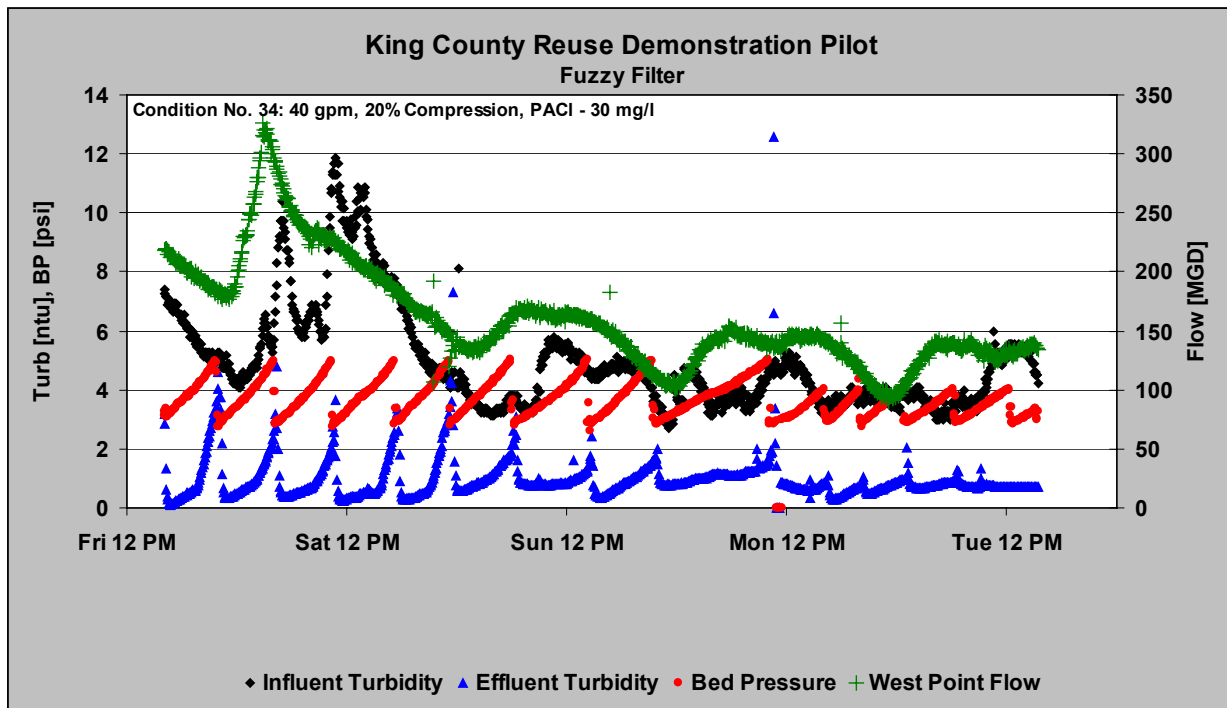
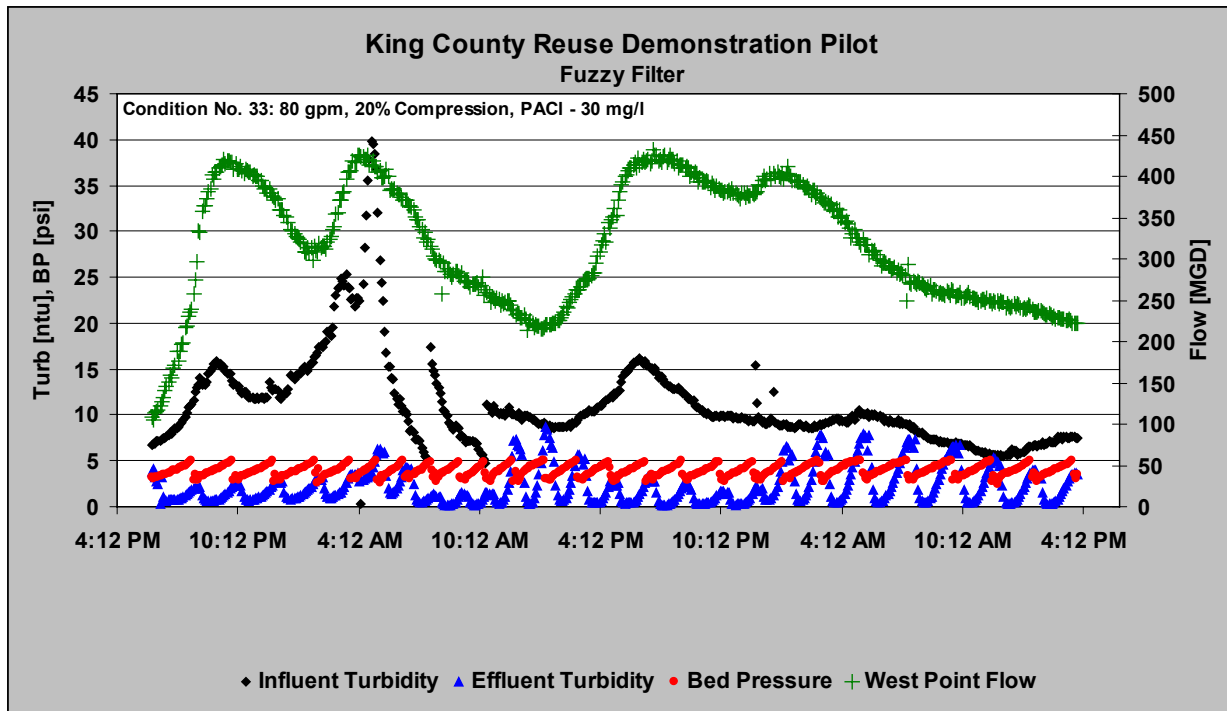


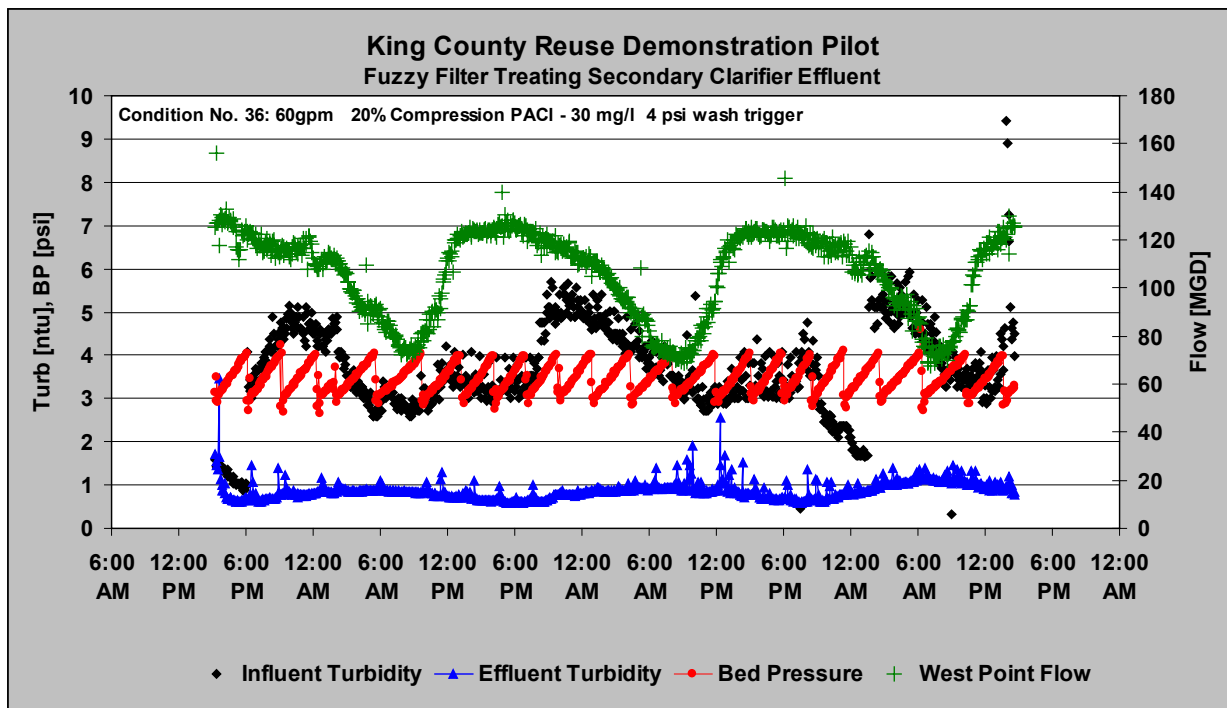
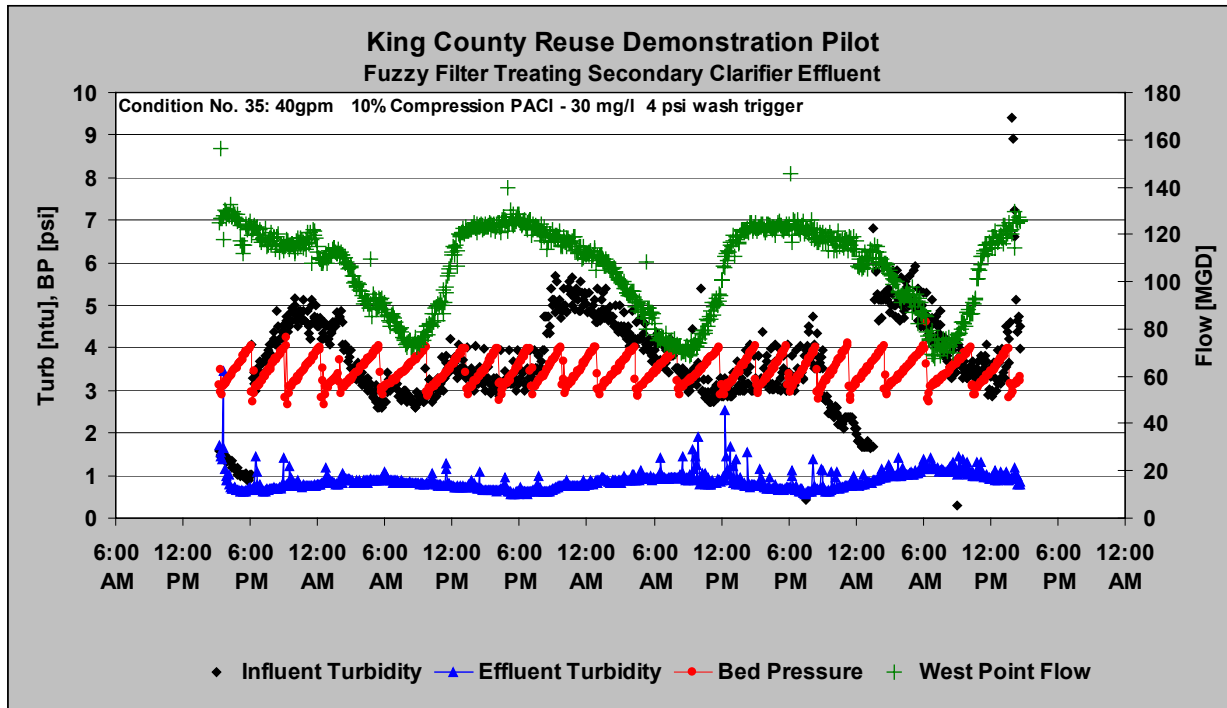


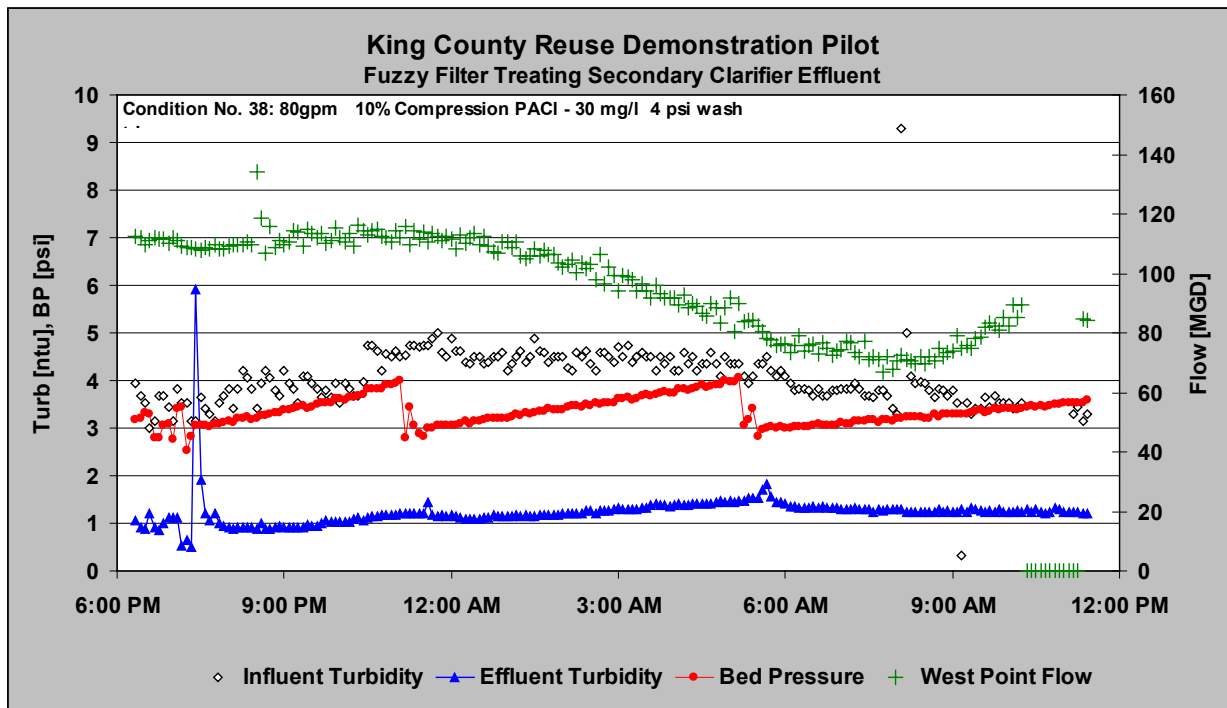
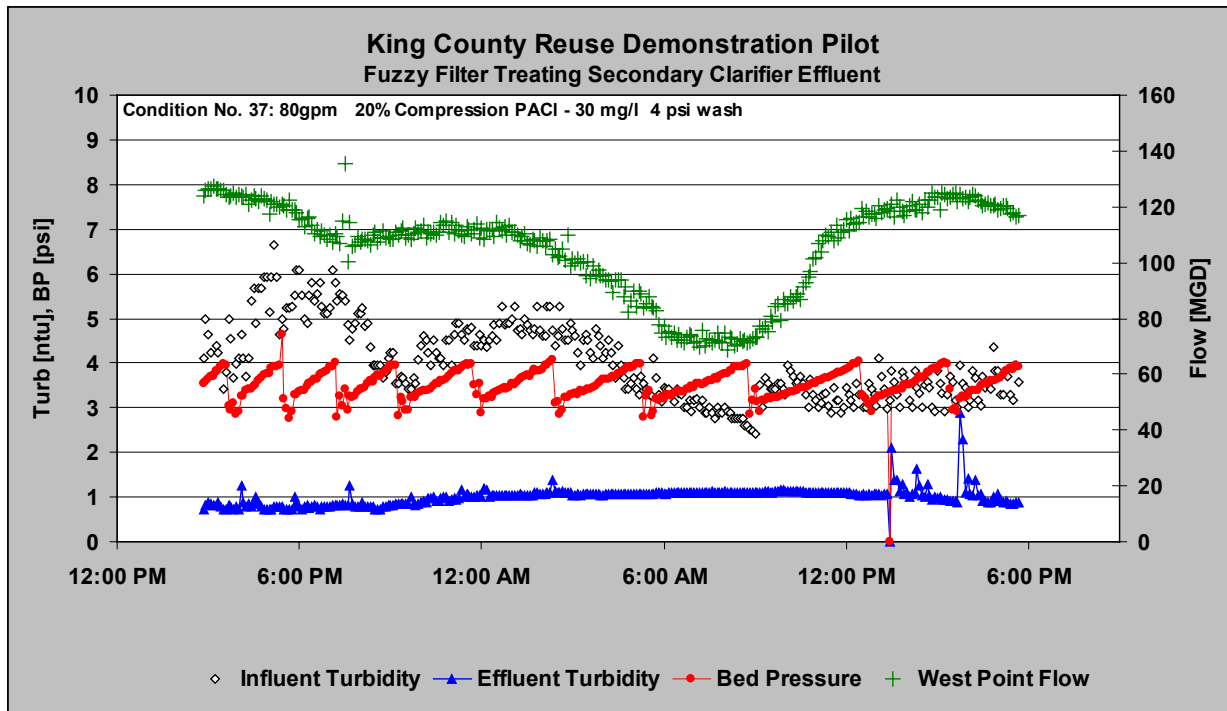


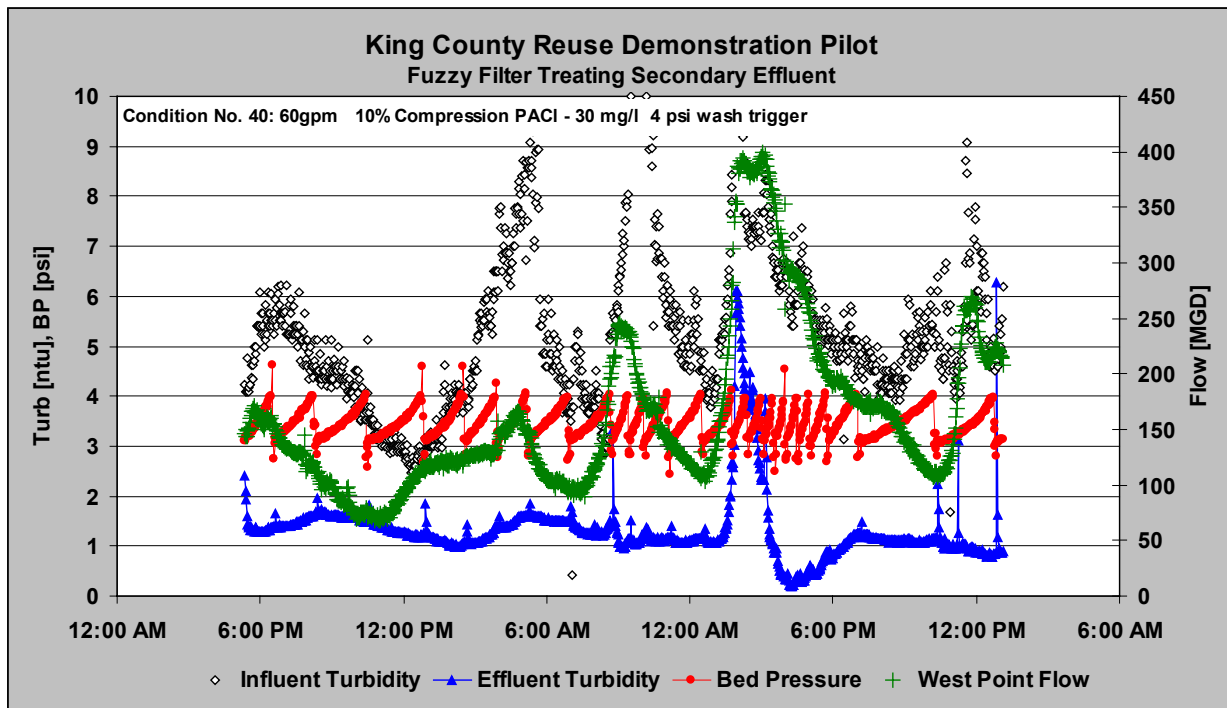
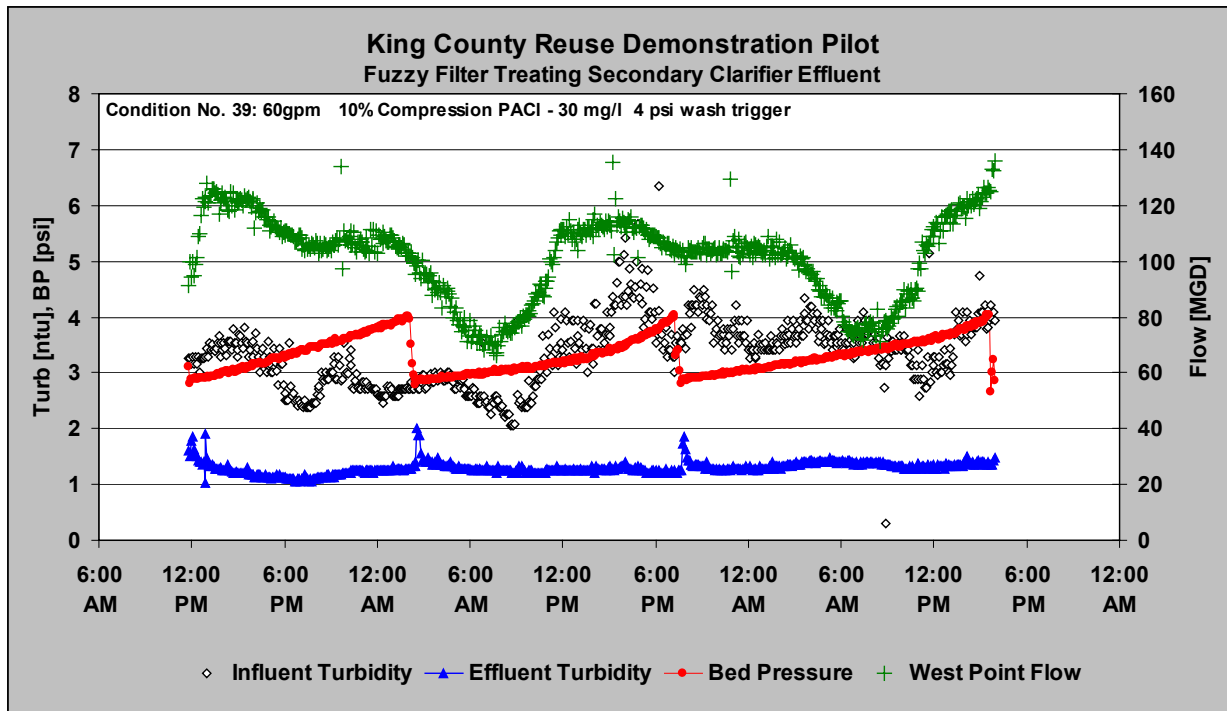


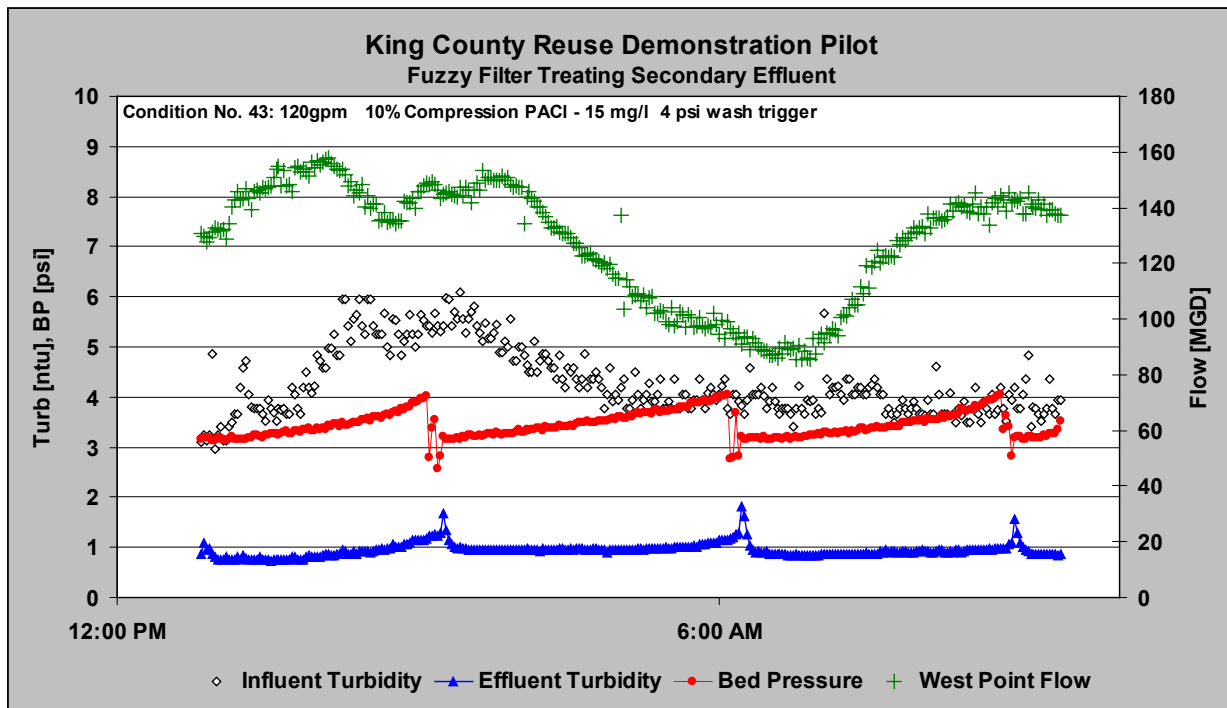
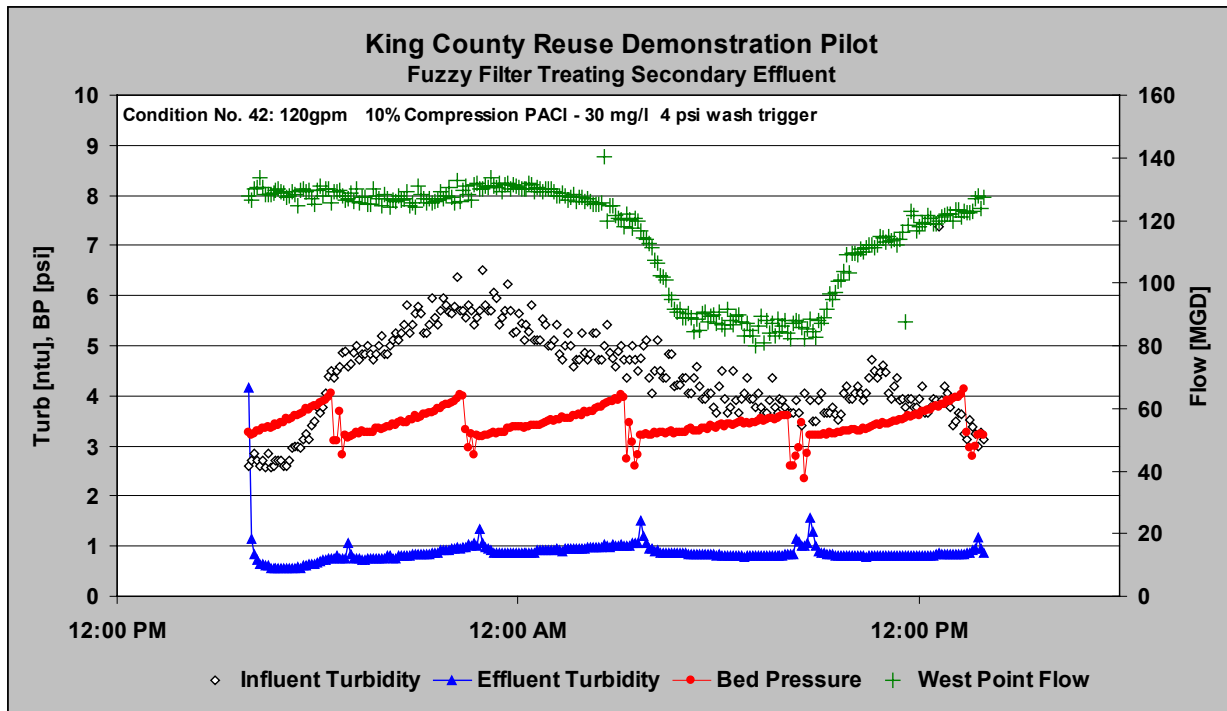


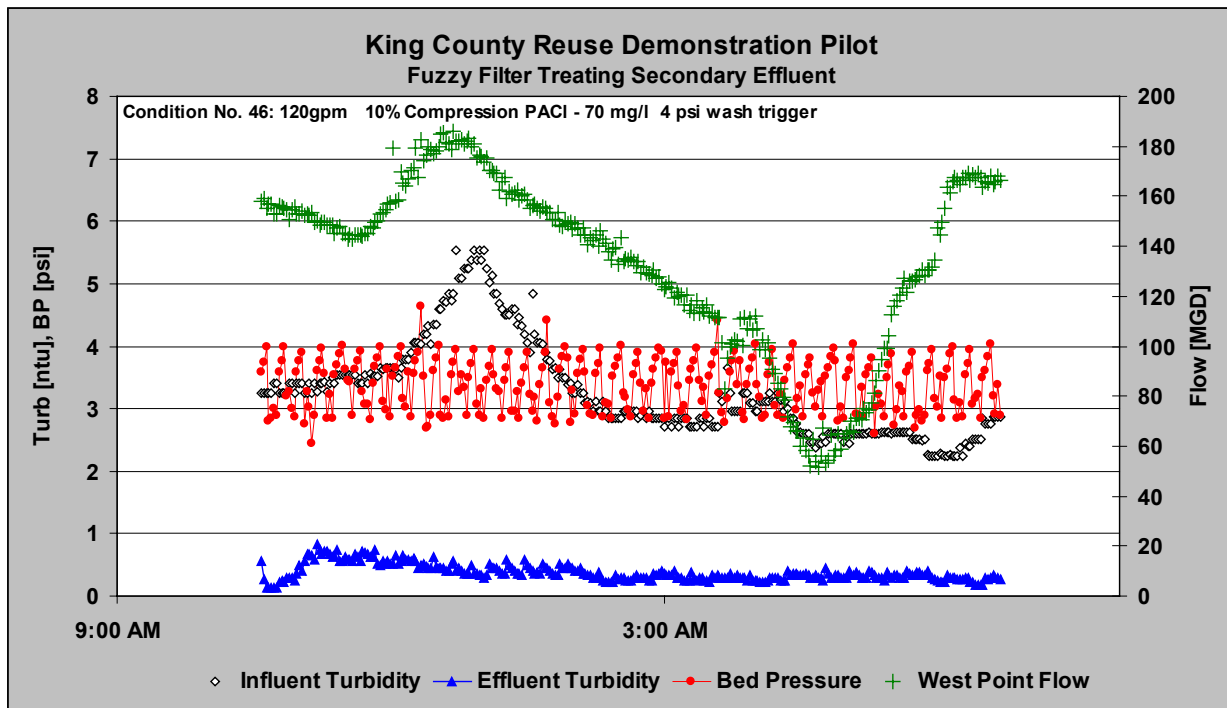
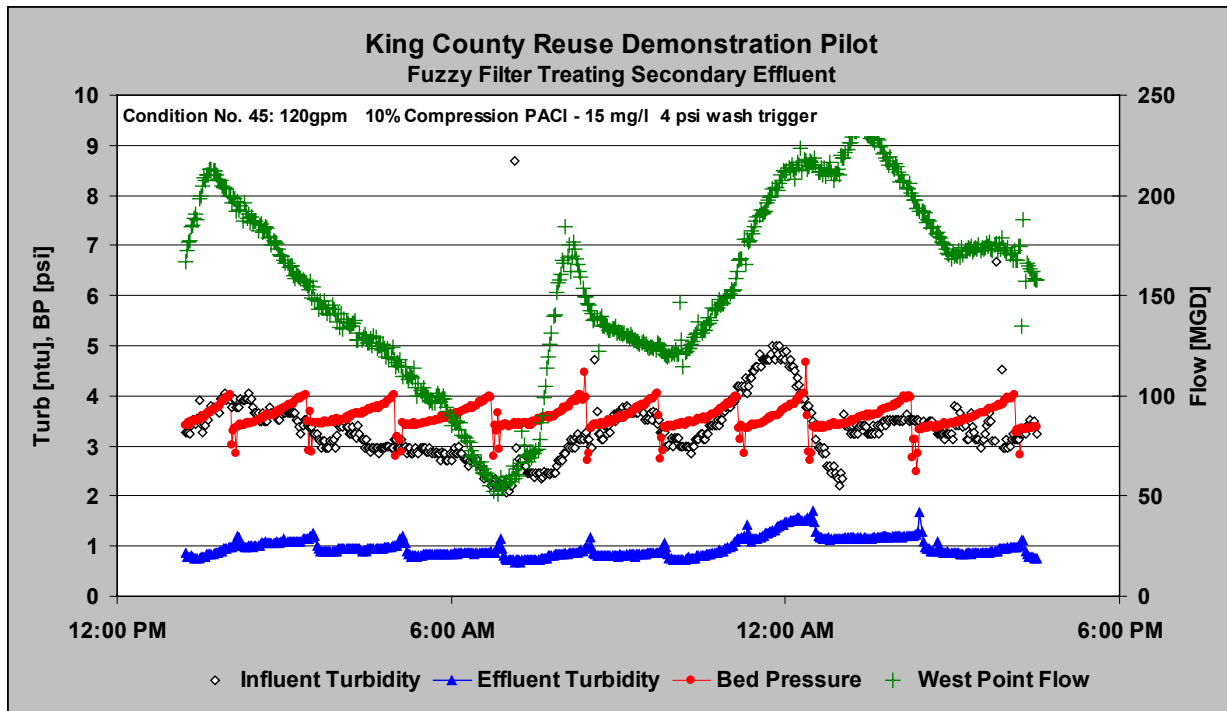


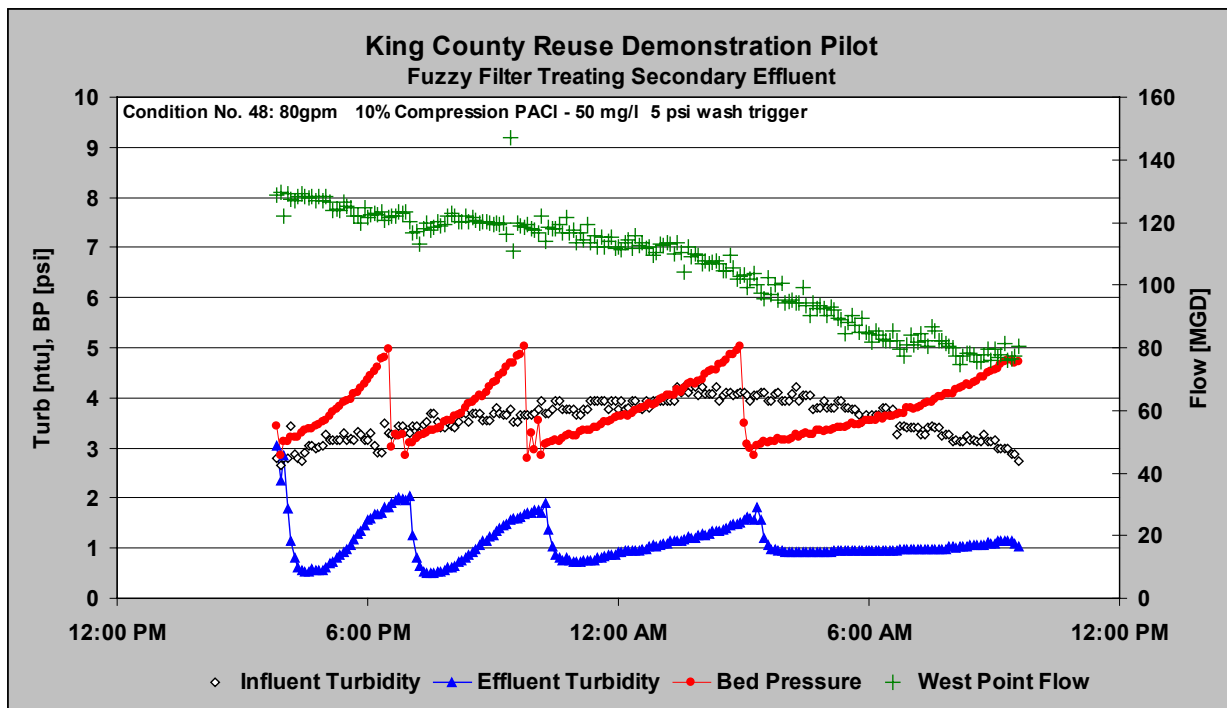
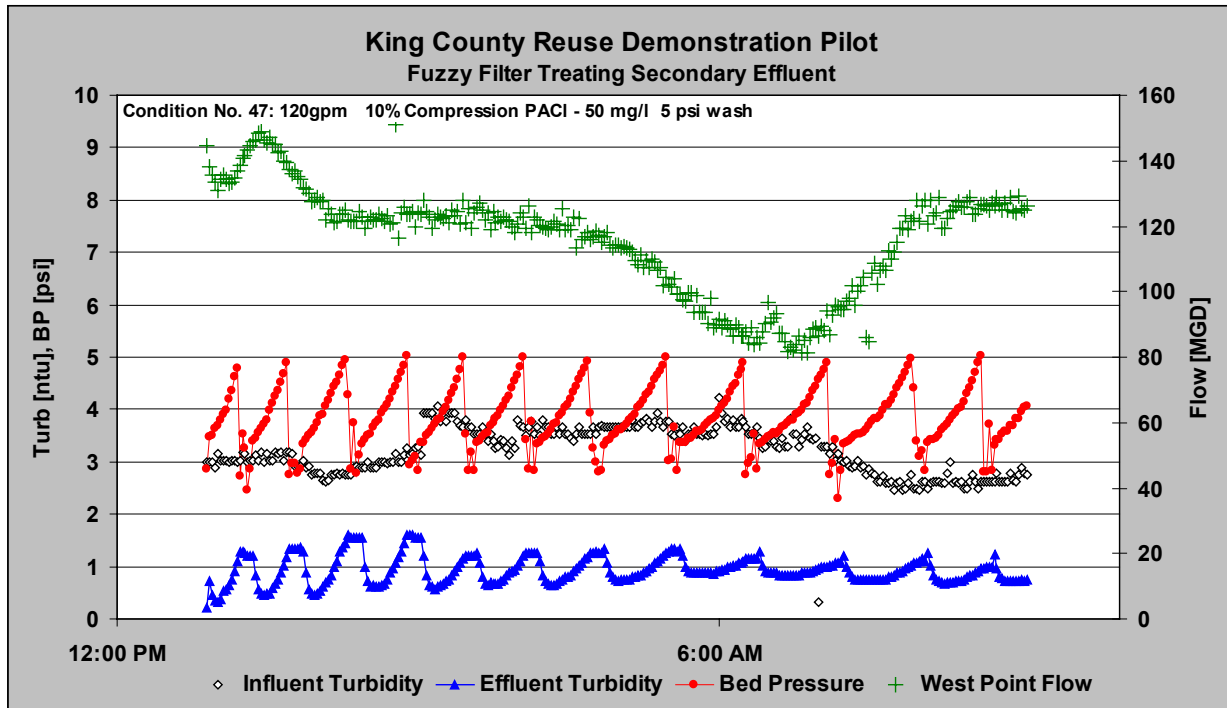


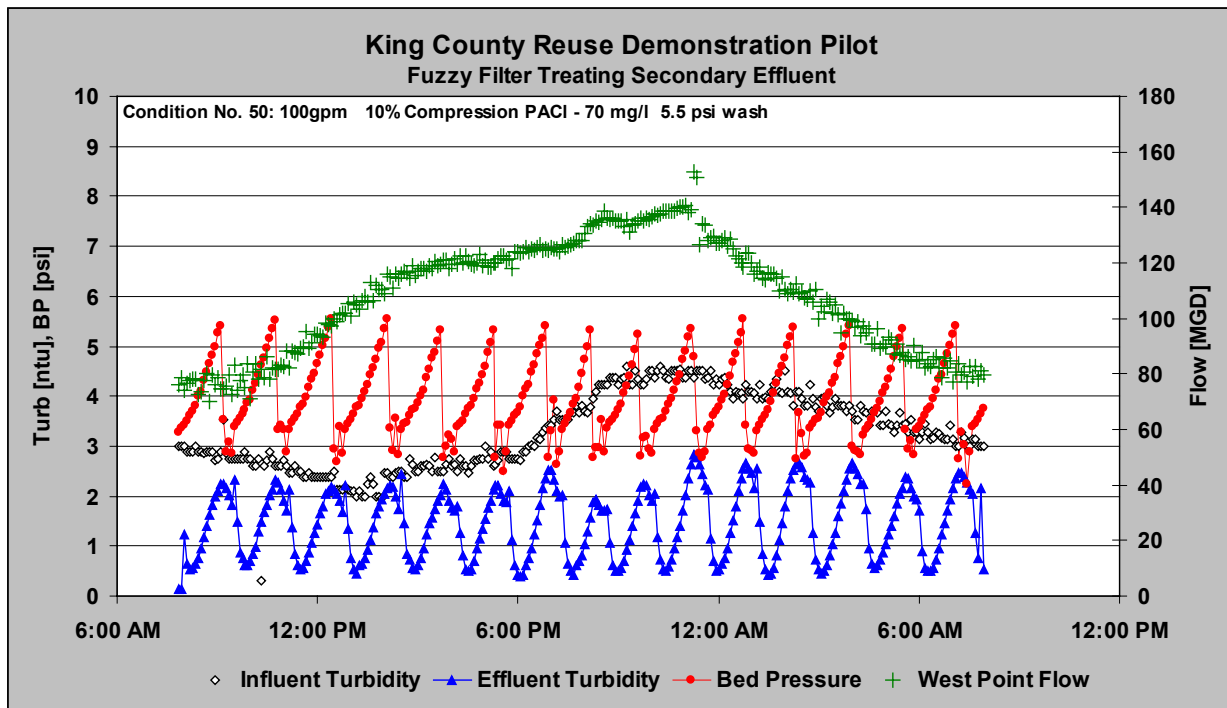
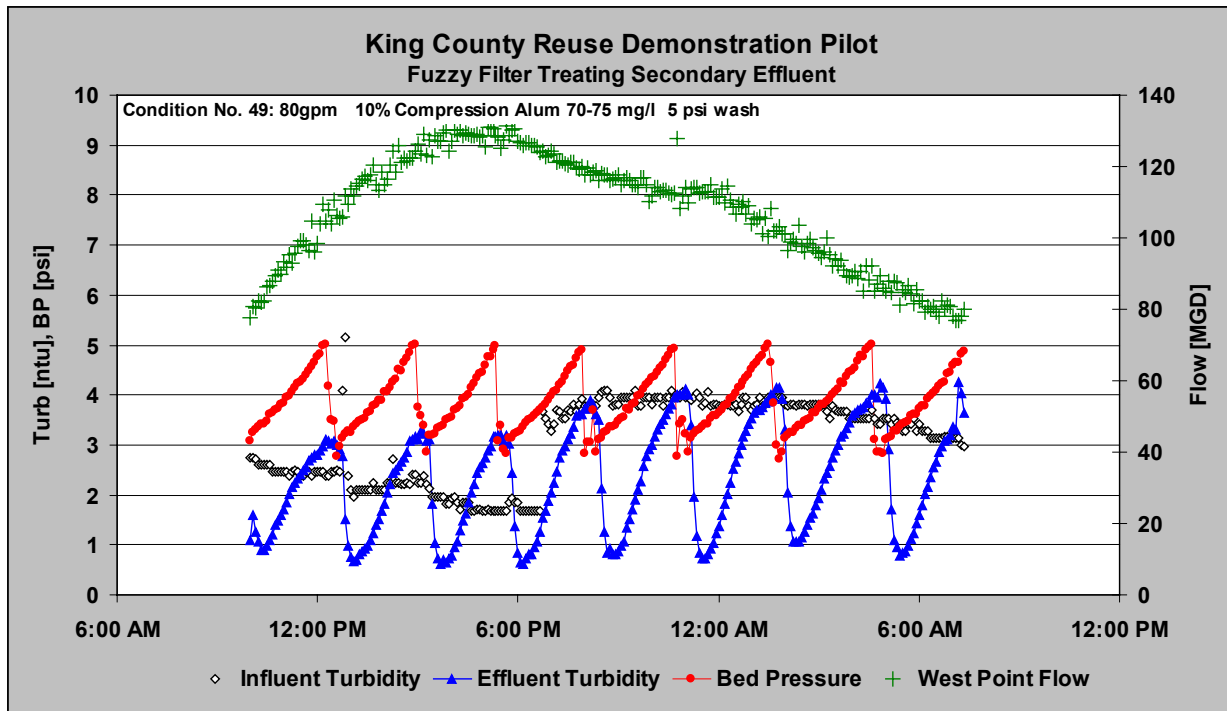












King County Water Reuse Demonstration Project - Fuzzy Filter

A-4 Summary of Test Conditions - Tertiary Treatment with Chemical Addition

This worksheet contains data taken during the final stage of the Fuzzy Filter wash cycle to investigate spikes in turbidity seen immediately after the wash cycle.

Date of test 3/22/2002

Filter conditions: 120 gpm, 10% compression, 5 psi backwash set point, 50 mg/L PACl

Step 7	stop watch elapse time	run time (min)	turb (ntu)
1'20"	1.33	1.33	19.2
2'05"	2.08	2.08	5.07
3	3.00	3.00	4.02
4	4.00	4.00	2.97
4'50	4.83	4.83	0.94

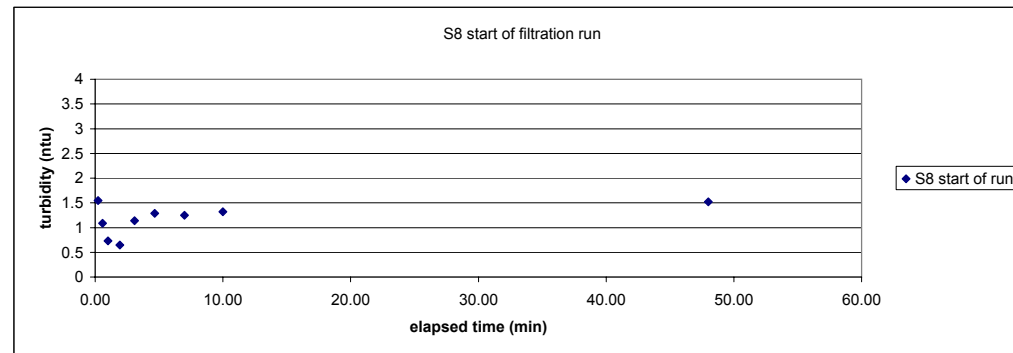
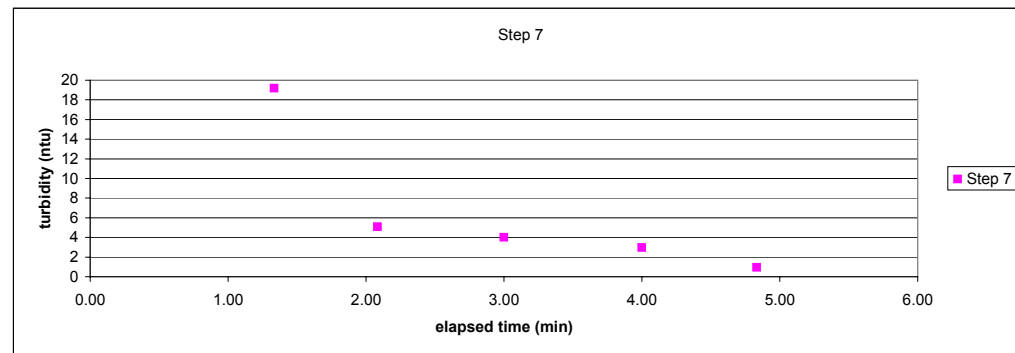
Filter run	stop watch elapse time	run time (min)	turb (ntu)
13"	0.22	0.22	1.55
35"	0.58	0.58	1.09
1	1.00	1.00	0.73
1'55"	1.92	1.92	0.65
3'05"	3.08	3.08	1.14
4'40"	4.67	4.67	1.29
7	7.0	7.00	1.25
10	10.0	10.00	1.32
48'	48	48.00	1.52

RO deionized water (squeeze bottle)	0.15
RO deionized water (tap)	0.11
RO deionized water (tap)	0.13
6.33 ntu	
check std	6.26

timer setup, step duration

	seconds	minutes	description	
step 1	150	2.50	air scour	750
step 2	150	2.50	air scour	155
step 3	150	2.50	air scour	350 5.833333
step 4	150	2.50	air scour	1255
step 5	150	2.50	air scour	20.9 sec
step 6	155	2.58	air scour	
step 7	350	5.83	compress and rinse	

sum 1255 20.92



King County Water Reuse Demonstration Project - Fuzzy Filter

A-4 Summary of Test Conditions - Tertiary Treatment with Chemical Addition

This worksheet contains data taken during the final stage of the Fuzzy Filter wash cycle to investigate spikes in turbidity seen immediately after the wash cycle.

Date of test 3/22/2002

Filter conditions: 120 gpm, 10% compression, 5 psi backwash set point, 50 mg/L PACl

Step 7	stop watch elapse time	run time (min)	turb (ntu)
1'20"	1.33	1.33	19.2
2'05"	2.08	2.08	5.07
3	3.00	3.00	4.02
4	4.00	4.00	2.97
4'50	4.83	4.83	0.94

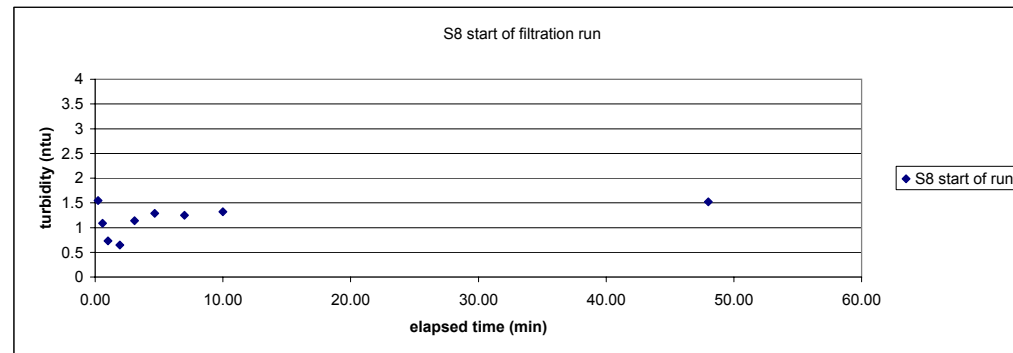
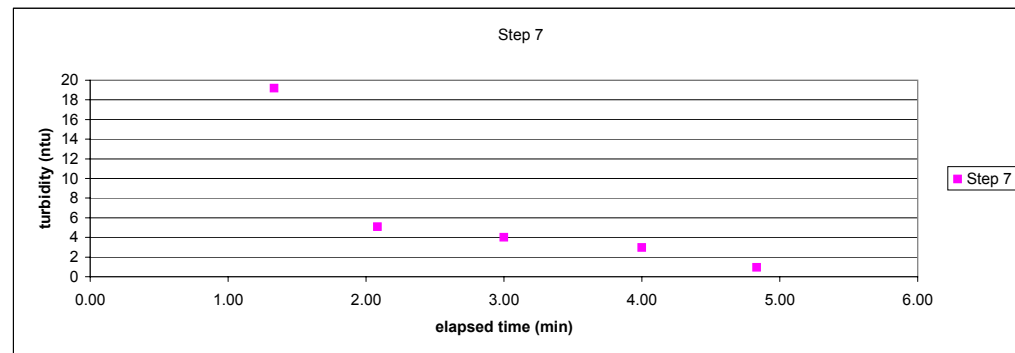
Filter run	stop watch elapse time	run time (min)	turb (ntu)
13"	0.22	0.22	1.55
35"	0.58	0.58	1.09
1	1.00	1.00	0.73
1'55"	1.92	1.92	0.65
3'05"	3.08	3.08	1.14
4'40"	4.67	4.67	1.29
7	7.0	7.00	1.25
10	10.0	10.00	1.32
48'	48	48.00	1.52

RO deionized water (squeeze bottle)	0.15
RO deionized water (tap)	0.11
RO deionized water (tap)	0.13
6.33 ntu	
check std	6.26

timer setup, step duration

	seconds	minutes	description	
step 1	150	2.50	air scour	750
step 2	150	2.50	air scour	155
step 3	150	2.50	air scour	350 5.833333
step 4	150	2.50	air scour	1255
step 5	150	2.50	air scour	20.9 sec
step 6	155	2.58	air scour	
step 7	350	5.83	compress and rinse	

sum 1255 20.92



King County Water Reuse Demonstration Project - Fuzzy Filter
Appendix E - Summary of Laboratory Results - Effluent

Date	Turbidity NTU	tBOD mg/L	sBOD mg/L	tCOD mg/L	sCOD mg/L	TSS mg/L	VSS mg/L	NH4 mg/L	NO3 mg/L	TKN mg/L	ortho P mg/L	TP mg/L	TOC mg/L	Alk mg/L	Cond.	pH
10/14/2001																
10/15/2001																
10/16/2001																
10/17/2001																
10/18/2001																
10/19/2001																
10/20/2001																
10/21/2001																
10/22/2001																
10/23/2001																
10/24/2001				417		206	180	13.46								
10/25/2001																
10/26/2001																
10/27/2001																
10/28/2001				454	228	156	132							160		
10/29/2001				740		274	226			37.35	4.37	6.55				
10/30/2001				430		259	189							106		
10/31/2001				472		188	159									
11/1/2001				ns	ns	ns	ns							160		
11/2/2001																
11/3/2001																
11/4/2001				357	200	ns	ns							126		
11/5/2001				405		189	137									
11/6/2001				490	184	170	147	15.7			2.82			156		
11/7/2001						ns	ns	15.8		27	3.7	6.22				
11/8/2001				397	191	156	128	17.9						167		
11/9/2001											3.82					
11/10/2001																
11/11/2001																
11/12/2001						165	119	13.5			2.12					
11/13/2001				289	107	118	79	6.6		13.9	1.61	2.67				
11/14/2001						61	36	2.9			0.73			67		
11/15/2001				246	143	240	119				1.01	2.4		91		
11/16/2001																
11/17/2001																
11/18/2001																
11/19/2001						82	62									
11/20/2001																
11/21/2001																
11/22/2001																
11/23/2001																

Date	Turbidity NTU	tBOD mg/L	sBOD mg/L	tCOD mg/L	sCOD mg/L	TSS mg/L	VSS mg/L	NH4 mg/L	NO3 mg/L	TKN mg/L	ortho P mg/L	TP mg/L	TOC mg/L	Alk mg/L	Cond.	pH
11/24/2001																
11/25/2001																
11/26/2001				80		2	2									
11/27/2001																
11/28/2001																
11/29/2001																
11/30/2001																
12/1/2001																
12/2/2001																
12/3/2001																
12/4/2001																
12/5/2001																
12/6/2001																
12/7/2001																
12/8/2001																
12/9/2001																
12/10/2001																
12/11/2001																
12/12/2001																
12/13/2001																
12/14/2001																
12/15/2001																
12/16/2001																
12/17/2001																
12/18/2001																
12/19/2001																
12/20/2001																
12/21/2001																
12/22/2001																
12/23/2001																
12/24/2001																
12/25/2001																
12/26/2001				85		2	2									
12/27/2001																
12/28/2001																
12/29/2001		6		87		2	0					1.24				
12/31/2001																
1/1/2002			79			13	12				1.54	1.82				
1/2/2002	3.97					5	3									
1/3/2002			3	37		1	0				1.41	1.47				
1/4/2002																
1/5/2002																
1/6/2002																
1/7/2002			13	66		13	8				0.62	0.78				
1/8/2002			4	77		4	3				0.71	0.9				
1/9/2002	1.25		5	52		5	4				0.89	1.04				

King County Water Reuse Demonstation Project
Fuzzy Filter
Effluent Samples
E - Laboratory Data

Date	Turbidity NTU	tBOD mg/L	sBOD mg/L	tCOD mg/L	sCOD mg/L	TSS mg/L	VSS mg/L	NH4 mg/L	NO3 mg/L	TKN mg/L	ortho P mg/L	TP mg/L	TOC mg/L	Alk mg/L	Cond.	pH
1/10/2002	1.89			122		4	1									
1/11/2002																
1/12/2002																
1/13/2002	2.42		4	100		8	4				1.22	1.37				
1/14/2002	2.7			92		4	2				1.63	1.72				
1/15/2002				146							1.92	2.02				
1/16/2002	2.73	6		142	118	6	2			4.14	1.77	1.14				
1/17/2002																
1/18/2002																
1/19/2002																
1/20/2002																
1/21/2002																
1/22/2002																
1/23/2002	2.71	12	8	188	180	1	0			13.72	2.72	2				
1/24/2002	4.42					5	2									
1/25/2002																
1/26/2002																
1/27/2002																
1/28/2002	3.36	8		195		4	2				1.23	1.34				
1/29/2002	3.39			391		9	7				1.47	1.66				
1/30/2002				196		6	4				0.976	1.72				
1/31/2002	8.28			297		17	10				1.36	1.44				
2/1/2002																
2/2/2002																
2/3/2002																
2/4/2002	4.6	10		258		15	7					1.6				
2/5/2002	5.98	10		150		11	10				0.55	1.58				
2/6/2002						9	6									
2/7/2002	7.49	12		127		14	8					0.82		111	667	7.11
2/8/2002																
2/9/2002																
2/10/2002	4.5	8		132		9	7					0.87		111	746	7.46
2/11/2002	4.08	3		152		14	8				0.43	1.47		103	701	7.2
2/12/2002	4.09	4		110		11	6				0.69			121	741	7.57
2/13/2002	6.74	8		162		8	6				2.52	2.28		146	802	7.26
2/14/2002	8.71			125		11	8				2.52	2.35		133	698	7.26
2/15/2002																
2/16/2002																
2/17/2002																
2/18/2002	3.03					8	4				0.47	1.15		116	717	7.27
2/19/2002	2.81	5		83		13	5				0.43	0.33		104	707	7.14
2/20/2002	3.01	8		337		8	5				0.36	0		124	707	7.19
2/21/2002	3.5	4		162		6	4				1.13	0		37	239	6.85
2/22/2002																
2/23/2002																
2/24/2002	3.53	5				9	4				0.33	0.61		104	495	7.28
2/25/2002	2.36	5		194		8	4				0.43	1.28		120	582	7.07

King County Water Reuse Demonstration Project
Fuzzy Filter
Effluent Samples
E - Laboratory Data

Date	Turbidity NTU	tBOD mg/L	sBOD mg/L	tCOD mg/L	sCOD mg/L	TSS mg/L	VSS mg/L	NH4 mg/L	NO3 mg/L	TKN mg/L	ortho P mg/L	TP mg/L	TOC mg/L	Alk mg/L	Cond.	pH
2/26/2002	2.33	3		130		6	2					0.55		124	760	7.42
2/27/2002	1.9	4		92		12	9					0.45		122	706	7.38
2/28/2002	2.6	6		121		11	7				0.45	0.83		124	851	7.25
3/1/2002																
3/2/2002																
3/3/2002	1.26	6		220		7	5				1.05	1.09		131	770	7.36
3/4/2002		4		190		6	4				0.75	1.23		127	748	7.48
3/5/2002	1.82	11		247		8	5				0.92	0.92		128	800	7.38
3/6/2002	2.1	9		246		8	4				1.27	1.94		170	916	7.68
3/7/2002																
3/8/2002																
3/9/2002																
3/10/2002	1.93			205		5	3				0.89	0.93		152	800	7.27
3/11/2002				142		5	5				0.25	0.37		43	397	7.04
3/12/2002	2.01	9		184		5	3				1.2	1.3		89	740	7.36
3/13/2002		10		202		4	3				0.98	1.19				
3/14/2002		10		166		2	2							123	668	7.32
3/15/2002																
3/16/2002																
3/17/2002		8		205		2	2				1.26	1.45		125	662	7.37
3/18/2002		11		194		4	1				1.2	1.6			635	7.59
3/19/2002		20		241		7	7				1.41			114	584	7.39
3/20/2002				151		5	5				0.01	0.02		75	400	7.16
3/21/2002				70		8	4				0.33	0.76		111	570	7.28
3/22/2002	2.02			106		7	4				0.64	1.31		130	700	7.39
3/23/2002	3.27			89		12	4				0.0	0.77		105	698	6.97
3/24/2002				104		13	7									
3/25/2002														121	669	7.4

King County Water Reuse Demonstration Project - Fuzzy Filter

Appendix F- Operator Notes

Date	Comments Entered on Operator Data Sheets	Comments from Operations Log Book
8/2/2001		Fuzzy Filter 1 (2ft X 2ft) delivered at 1300 hrs. Delivered equipment: 2 skids (filter and blower/control panel), 1 box of loose spare parts.
8/3/2001		Working on skid installation. Shinn mech anchored skids and started plumbing feed filtration, and backwash lines to facility.
8/4/2001		
8/5/2001		
8/6/2001		Shinn continued on fuzzy filter install. Prime electric work on power and DH+ cable. Completed new C2 backwash system, only need to add check valves. Expect Schreiber onsite Thursday and Friday.
8/7/2001		Shinn continued mechanical install - connected WS1 to feed pump 1.
8/8/2001		Mechanical and electrical hookup completed. Portland Engs completed SCADA system update and reconfiguration for new feed flowmeter. Also completed controls for solenoid valve or C2 backwash source.
8/9/2001		Adrian Carrollan onsite for fuzzy filter startup. Reviewed installation and forced to wait for control system document from Schreiber prior to continuing. Discussed preliminary test series with Adrian test conditions are noted in log book. Expect Schrei
8/10/2001		Schreiber (Adrian) back to finish skid setup. Control systems manual "full scale" filter operating sequence and media cleaning procedure provided. Following corrective actions indentified from checkout: switching the manual mode during active auto filter
8/11/2001		
8/12/2001		
8/13/2001		Repaired backwash line leak. Also installed bleed on backwash line to dissipate scour air flow to drain system. Setup effluent sampler. Set new PRV on C2 backwash line.
8/14/2001		Completed install of check valves in feed and backwash lines. Discovered that backwash solenoid valve is energized (forced in PLC logic - Portland Eng checkout on 8/8). Will have maintenance inforce logic.
8/15/2001		Idle
8/16/2001		Prepared for functional checkout of skid using C2 water. Plant to run for duration of day shift tomorrow. Operated Fuzzy Filter feed pump FP1. Ready for skid testing. Planned skid checkout configuration with C2.
8/17/2001		
8/18/2001		
8/19/2001		
8/20/2001		
8/21/2001		
8/22/2001		
8/23/2001		
8/24/2001		
8/25/2001		
8/26/2001		
8/27/2001		Run with C2, backwash. Set "0"-compression by draining wet fluffed media. Bring top plate down to touch top of media. Lower plate is approximately equal to level of bottom window. Lower plate distance from top plate at 0% compression is approximately 3
8/28/2001		Run filter with screened raw sewage (PI or primary influent) start at 1018 hrs at 20 gpm and 0% compression. Flow tails off, need to open influent valves to bring flow back to 20 gpm total. Done twice in first 1.25 hours by opening DV-10 valve. Digital
8/29/2001		Top plate level transmitter non-functional. Wait for vendor to fix. Alan Vogt left the site recommended to Schreiber that they send out Electrical person. Recommends not running until fixed. Drain FF so C2 water can run through FM to drain. Ran C-2 t
8/30/2001		Portland Eng are to be hired by Schreiber to repaid skid. Schreiber will ship new transmitter for install. Portland will also cleanup other PLC ladder logic problems. Expect work to be completed by 9/12 (Wednesday).
8/31/2001		
9/1/2001		
9/2/2001		
9/3/2001		
9/4/2001		
9/5/2001		
9/6/2001		
9/7/2001		
9/8/2001		
9/9/2001		
9/10/2001		
9/11/2001		
9/12/2001		
9/13/2001		
9/14/2001		Received new level transmitter from Schreiber. Also provided with remote modem. Portland Engs will install early next week.
9/15/2001		
9/16/2001		
9/17/2001		At 0800 hrs talked with Francis at Portland Eng. He will be onsite tomorrow to install equipment.
9/18/2001		Francis here, level transmitter installed, he is also working to make PLC changes from Schreiber workable. Says it will be OK to run before he elaves this evening.
9/19/2001		At 1200 hrs set 0% calibration of FF top plate 35 inches bottom plate, 9.5 inches above bottom of tank stiffener band. At 1255 hrs added C2 water from hose to wide spot tank. Set wash cycle iterval at 2 hours. At 1300 hrs switch to AUTO, top plate cam
9/20/2001		
9/21/2001		

Date	Comments Entered on Operator Data Sheets	Comments from Operations Log Book
9/22/2001		
9/23/2001		
9/24/2001		
9/25/2001		Contractor completed installation of C3 in line to wide spot tank #1 (2 inch line).
9/26/2001		Run C-3 through filter at 25 gpm. Run backwash cycle, full cycle. Turn off flow to FF, add 1.1 L and 6% bleach to (approximately 1000 ppm). Filter drain vent (Drain valve closed). Level in filter had drained to top of window. Run wash cycle, no feed.
9/27/2001		
9/28/2001		
9/29/2001		
9/30/2001		
10/1/2001		
10/2/2001		
10/3/2001		
10/4/2001		
10/5/2001		
10/6/2001		
10/7/2001		
10/8/2001		
10/9/2001		
10/10/2001		
10/11/2001		
10/12/2001		
10/13/2001		
10/14/2001		No comments.
10/15/2001		Flow control valve still not here. Run tests with primary influent anyway. Set 0% calibration to top plate per page 14, does take. Primary influent is feed to Wide spt tank #1. 0% compression is 33.25", FF at "0%" compression is at 33", LCP shows 40" is zero, was at 39" earlier, but actual distance above bottom plate is 33". Run backwash cycle, stink water to drain at end of cycle, came back to rest at 0% compression 34.5", reads out at 40" on LCP. Valves not repeatable. Problem with top plate gasket. Problems to discuss with Schreiber: FF (PLC?) LCP shows 0% compression = 40", is it not, 0% compression is around 35" per A Vogt; Cannot set zero at 35", compresses to approximatel 34.5 to 34.25" (increments of 1 inch); changing to % compression appears to be not repeatable.
10/16/2001		Rain returns this AM. Start flow testing with PI, even without resolveing problems noted previously. Bed depth = 33.5" = 5%. PI flow = 20 gpm (adjusted fpm at valve DV10). At 1155 hrs start flow. At 1210 hrs effluent is turbid, FF medium is trapping solids, 1st 11" of bed are accumulating at winidow. Did no clean out effluent turbidimeter before start of run. At 12224 hrs 2.79 psi, flow at flowmeter 20+ gpm, at SCADA 19.9. At 1615 hrs flow at 19.1 gpm, P=2.79 psi, 30.1 NTU. Floc settling on top plate, solids in bottom of filter, top plate returns to 33.5" bed depth. At 1625 hrs placed in manual, increase compression to 9%, actual depth of media 31.25" = 10% compression. Increase wash cycle frequency to 3 hrs. At 1632 hrs started wash cycle. Settling on top plate (start of new fill run_. Media depth returned to 31.25", 3 hr wash interval took into PLC. PI flow 19.5 gpm, open DV-10, new flow 20.5 gpm. Influent P is 2.78 psi. At 1655 hrs let system run in automatic overnight.
10/17/2001	At 1210 hrs, bed compression taken at LCP.	In early AM (4 to 5) Bucher noted high turbidity (LED flashing due to turbidity > 100 NTU), Flashed throughout morning, by 1000 hrs back at 30 NTU> Backwash occurred due to time, not pressure. Plan: increase compression to 15% = 29.75" bed depth and let run. Observed at 10% compression with 1 hour before next wash that solids accumulated in first 11" of bed, P = 2.91. With 25 minutes before next wash solids accumulated in window is same, P=2.92 psi. Flow is 18.8 gpm. Not much fluff on top of FF top plate. Change position of top plate, top plate will be below window. At 1140 hrs place in manual and increased compression to 14%. Screw at 25 5/8 too much. Cannot go back up. Appears that can increase but not decrease compression. At 1145 hrs set to 12% and initiated wash cycle (10 minutes earl of 3 hrs). SET to 11%. Screw at top during wash is 48.75" above top of FF. After wash top plate returned to 11% screw at 26.75". Bed depth 30.25". Increase to 12% on LCP gives 26.5" on screw. Increase to 13% on LCP gives 26.1666 on screw. Actual bed depth is 29.6" for 15.5% compression. Post wash flow is 18.8 gpm, open DV-10 increases flow to 20.5 gpm. Let system run.
10/18/2001	At 255 hrs, 55 minutes until next backwash. At 1640 hrs, bed compression taken at LCP.	At 1555 hrs 1 hr until next backwash (55') 90 NTU, P=3.02. Screw at 25 13/16". Actual bde depth is 29.31", 83.8% compression. Flow is at 19.8 gpm. At 1620 hrs initiated backwash, want to increase backwash (38 min to go) flow to 40 gpm (10 gpm/ft^2). At 23.3 gpm, open DV-10 to get 40.5 gpm. ADjust backwash pressure initiated to 1.75 psi above initial. Initial post-wash P is 2.9 psi/ This would be 4.65 psi, but 4.75 psi used due to allowance of increments of 0.25 only. Adjust primary influent flow to 20 gpm by partially opening valve DV-9, which recycles PI into widespot tank through/via the pump. During purge, lots of particulate matter floating above top plate. Increasing compression to 20% target 28", top screw at 24.5". 15% at LCP = 25.25", 16% = 25", 17% = 24 5/16". 20.5% compression. At 1435 hrs flow is 20 gpm, turbidity is 64 NTU, and pressure is 2.94 psi.
10/19/2001		No comments.
10/20/2001		No comments.
10/21/2001		Cleaned turbidimeter and rotometer, and adjusted flow from 0920 to 1046 hrs.
10/22/2001	Reading at 1255 hrs: bed compression taken at LCP; headloss before backwash is 45 minutes before 3 hours backwash.	At 1245 hrs no flow to FF; bubbles entering FF via feed line. At 1250 hrs flow at 22 gpm, don't know why it's flowing again. Turbid effluent; cleaned out turbidimeter sample line, rotameter, turbidimeter with water (C2); clean autosampler bucket; hooked up new power supply to Isco autosampler (model 2900). At 1330 hrs effluent looks horrible, entire depth of visible media is covered by primary solids, at 1245 hrs only the first third or so was covered in solids. Effluent turbidity is 74 NTU, pressure 3.13 psi. Top plate returns to 24 5/16" (20.5%). Initiated new wash, washwater flow is 40.8 gpm, same with 1 purge blower running. Increase compression to 25%, bed depth of 26.25 inches, 1.75" below 20% compression. Screw measurement is 22.75". Increase to 19% compression at LCP gives 23.50" on screw. Increase to 20% compression at LCP gives 23.38" on screw. Increase to 21% compression at LCP gives 22 15/16" (22.98") on screw. 21% compression at LCP, actual bed depth is 26.44 inches (24.5% compression). Initial pressure is 2.9, backwash set at 4.75 psi. Flow at 21.5 gpm, DV-9 fully open, for further adjustment will need to pinch DV-10 re-set PCV, leave it for now. Autosampler needs extension cord.
10/23/2001		At 1620 hrs unit is black, LCP screen shows next wash to occur in 2:59:59, same as when I left yesterday. Initiate wash. C2 flow at 40 gpm during wash. Clean turbidimeter and auto-sampler bucket. System not running. Reset feed pump at local control panel, switch abck to AUTO, system started. Leave it to run flow at 25 gpm. Adjust from 20 to 18.5 gpm at DV-10. 3 hr backwash interval, pressure of 2.68 psi.

Date	Comments Entered on Operator Data Sheets	Comments from Operations Log Book
10/24/2001	At 1015 hrs headloss before backwash taken at mid cycle, 1.5 hours until next backwash.	Primary influent flow meter alarms coming in, flow is good, Susan says it reaches high flow set point, alarms, drops back, then up and alarm. Fuzzy filter flow at 15 gpm. Jook up autosampler to power (new extension cord). No flow to autosampler. Adjust feed flow to 20.5 gpm with DV-9. Screw height at 22 13/16", bed height at 26.31" (75.2% compression). Flush line to autosampler line, restored flow. Flush turbidimeter line, drain and wash turbidimeter clean out turbidimeter flow meter. Open turbidimeter valve at FF, flow to auto-sampler bucket stopped. Pinch turbid flow valve to 0.5 L/min, restored flow to autosampler bucket. Increase bed compression to 30% (24.5" bed depth, screw height 21"). At LCP 25% compression has a screw height of 21.25 inches (29.3% compression), 26% compression has a screw height of 20.875 inches (30.4% compression). Used 26% compression. Cleaned autosampler bucket. backwash cycle started C2 flow of 30 gpm, to increase to 32 at DV-10, increase to 40.2 gpm at CLA-PRV. End wash - screw returned to 20.75". Pressure is 2.81 psi+1.75 psi = 4.56, decrease backwash setpoint to 4.50 psi. Susan to set up autosampler. At 1545 hrs started S8 sampler. Sample volume of 80 mL.
10/25/2001	At 0140 hrs turbidity increased from 27.76 to 48.03 NTU after flow adjustment. Adjusted turbidity flow to 0.65, lots of junk in the line.	At 1620 hrs filter bed is black, 30 minutes before next wash. Back pressure is 3.40 psi. No flow to turbidimeter, Bucher restored flow. Flow is 15.5 gpm, maybe reduced due to increasing inlet pressure. At 1640 hrs initiated backwash. Backwash flow of 40+ gpm. Initial filter flow of 225 gpm.
10/26/2001	Unit secured at 1646 hrs.	At 1646 hrs unit secured for weekend. FP1 to OFF position at local panel. Skid to manual position at control panel. Plan to restart unit on Sunday (10/28) morning.
10/27/2001	Unit secured.	No comments.
10/28/2001		Setup for 24 hour run. Pressure approximately 4.5 psi, compression of 10% (31.75"). (0% = 35": per 9/20 note, 0% is 9.5 inches above bottom of tank stiffener. Therefore, 10% is 5.75" above stiffener). Set backwash timer at 24 hours. Started unit at 0903 hrs, 20 gpm feed flow. Autosampler also started. Turbidimeter setup with flowrate of 0.6 L/min.
10/29/2001	At 1004 hrs adjusted feed flow from 20 to 40 gpm. At 1141 hrs adjusted turbidimeter flow. At 1436 hrs switch sample and turbidimeter lines. Re-established flow to turbidimeter.	At 0924 hrs unit completed backwash, 24 hour run complete. Adjusted feed flow to 25 gpm for 24 hour run. Also adjusted flow to turbidity meter. At 1104 hrs adjusted feed flow to 40 gpm using DV10 (pump recirc valve fully closed). At 1141 hrs adjusted turbidimeter flow from 0 to 0.7 L/min. From 1000 to 1045 hrs conference call with HDR to discuss pilot operation and Test Planning. HDR will distribute recised table 4 from Test Plan to guide testing for next two weeks. At 1436 hrs re-established flow to turbidimeter. At 1600 hrs re-located turbidimeter feedtap to existing ball valve on effluent (upstream of filtration iso-valve). Important to note that this location will see effects of abckwsh cycle. Location slected due to availability of ball valve flow control.
10/30/2001	At 0955 hrs did not adjust flow. (C2 wash water stuck on in PLC program)	At 0950 hrs after wash cycle, noted the following: feed flow at 58 gpm; effluent sample bucket has lots of solids deposition (not sure if from backwash); turbidity dropped to 13.6 NTU. At 100 hrs set feed flow at 60 gpm (discovered that flow is 60 gpm of C2 water - feed pump secured). At 1045 hrs discovered problem with fuzzy filter operation. Unit stuck in backwash (facility side). c2 water flow to skid with feed pump 1 off - caused by I/C contractor secure of facility SCADA system during backwash. Re-initiated backwash to clear stuck contact in PLC program - worked. At 1106 hrs started unit and operating at 60 gpm feed flow (feed flow adjusted at DV-10 valve). Forced to run feed pump in manual - I/C contractor will troubleshoot problem with remote operation. At 1115 hrs fuzzy filter effluent sampler started. Back off C2 PRV 3 full turns (Cla-valve), to decrease backwash C-2 flow. Compression check - at 44.5" from bottom of unit, 5 inches above stiffener band (ref page 14) (9.5-5) is 4.5 inches below 35 inches. 4.5/35 is 12.9% compression. Actual screw height is 27 1/8", screw at 0% is 31.5", 4.375" less than 35" bed depth of 30.625" 12.5% compression. Top plate has lowered approximately 5/8" from where Bob B not
10/31/2001	At 1140 hrs increased from to 81 gpm.	At 1130 hrs 30 minutes into filter run (post wash) flow is 74 gpm, should have been 60 gpm. Increased flow to 80 gpm. At 1135 hrs feed pump 1 kicked out. Bucher reset. Wide spot tank 1 overflowed during feed pump 1 outage. Bob investigating cause of kick out. Susan reported a high back pressure alarm kickout this am. Bob checking hard wire setting, units setting for backwash is 4.5 psi. Susan cleaned out sampler bucket and flow emter, bleached turbidity line. at 1533 hrs adjusted turbdiimeter flow from 0 to 0.8 L/min.
11/1/2001	Backwash completed at approximately 1110 hrs. New backwash at 1420 hrs.	At 0414 hrs adjusted turbidimeter flow from 0 to 0.8 L/min. At 0830 hrs adjutsd turidimeter flow from 0 to 0.8 L/min. At 1010 hrs adjusted turbidimeter flow from o to 0.8 L/min. Shut system off by Bucher. Today's test plan is at 20% compression with 10 gpm/ft^2 (40 gpm flow). Compression on touch screen is 10%, bed at 30.5", screw at 27", top plate at 5" above stiffener band. 20% compression has 28" bed depth, screw at 24.5 target. Touch screen 16% compression screw at 24 7/8". Touch screen 17% compression screw at 24.5", actual compression of 20%. Start flow to filter, adjust to 40 gpm at DV-10 to 40 gpm. Initiate wash at 22:56 hrs to go untio next wash. Adjust wash water flow to 40 at ClaValve from 47 to 40 gpm C-2, 2 complete turns CCW. Flow fluctuation in WS-tank, Bob shut off flow outside, adjusted primary influent valves and DV-4. Opened ball-valve to turbidimeter 100%, cleared out crud in line, pinched back to get flow to 0.8 L/min, 1st overtopped turbidimter cell. Rotometer sticks, thinking about removing it and reconfiguring lines to turbidimeter.
11/2/2001	Wash and secured unit until Sunday (11/4).	At 0730 hrs discovered feed pump 1 tripped out on thermal overload. Expect pump may have been cavitating during early morning primary influent pump shutdown. Reset feed pump and pump started. At 0815 hrs discovered no S4 sample composited in sampler. Sample line in overflow bucket not below surface - pulling air. Backwashed unit (initiated via screen at 0826 hrs) and plan to re-run condition on Monday 11/5. Unit secured for the weekend in auto mode (backwash will occur on sat and Sun).
11/3/2001		No comments.
11/4/2001		No comments.
11/5/2001		Maintenance issues: clean sample bucket; put in new line from bucket to autosampler; clean turbidimeter and feed and drain-lines; bypass turbidimeter flowmeter (rotometer). Run - new run, repeat 11/1 parameters. 20% compression, 40 gpm. At 1315 hrs placed FP in auto - flow started at 43 gpm, screw at 24 5/16 (17% compression readout at LCP). Adjust flow to WS tank 1 at PV-4 (open a bit), PV-3 (close a touch), and DV-4 closed. Lots of solids dropped off of screen. Feed pump kicking on and off in auto. Maybe a problem with upper or lower level sensor since tank level dropped before adjusted in earlier step. Leave FP in manual. At 1345 hrs 19.5 hrs until next wash. Manually sample first sample. Clean ball valve to turb. by backflush, start flow to turbidity meter.
11/6/2001	At 1535 hrs restored flow to turbidimeter.	Run at 20% compression with 40 gpm. Problems - intermittent flow to FF throughout yesterday's rung. Problem with maintaining level in WS tank 1. At 0800 hrs flow was 2 gpm, SA adjusted DV-4 to restore flow to WS. At 0930 hrs wash cycle. At 1130 hrs flow was 40 gpm, screw level at 24 5/6, 27 13/16 bed depth, restore flow to turbidimeter. At 1150 hrs drain and clean turbidimeter and autosampler bucket. At 1210 hrs manual sample autosampler, start sampler, 32 minutes until next autosample. At 1535 hrs no flow to autosampler bucket, open valve to restore flow, no flow to turbidimeter, open ball valve to restore flow. At 1653 hrs adjusted turbidimeter flow from 0 to 0.8 Lpm.

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11/7/2001	S4 grab sample. At 1355 hrs was no flow, got it going again.	At 1204 hrs 21:44 until next wash. Autosample bucket flow good, turbidimeter flow zero, adjust backflush and restored flow. Operation for today, increase flow to 15 gpm/ft ² (60 gpm, 61.5 actual). Adjust DV-10 to get flow of 61.5 gpm. At 1220 hrs initiate backwash, adjust Cla-Val in 3 full turns to adjust wash flow from 61 to 41 gpm. At 1230 hrs adjust DV-4 so WS tank 1 level does not draw down due to increased FF flow. At 1245 hrs flow at 66.5 gpm, adjusted at DV-9 1/2 turn open, empty sample container. At 1252 hrs FP kicking out in auto, reset and run in hand. Ball valve plugging, open to clear, pinch back to reasonable flow. Turbidimeter flow continues to be a problem. At 1300 hrs adjust DV-4, level in wide spot tank 1 was dropping. WSTK 1 level control continues to be a problem. At 1355 hrs turbidimeter flow is zero, open wide to clear, adjust closed.
11/8/2001		1000 check list, turbidity reading = 3, check turbidimeter. Lamp and lens caked over, ringse off. No flow to turbidimeter, restore flow. Level in turbidimeter floods lamp, back off flow at ball valve, rinse drain line. Clean and drain turbidimeter. Autosample bucket - tube pulled out, collected only 200 mL. Flow to bucket is good. Drain sample bucket and rinse. Connect turbidity line to same penetration as autosample bucket. Ball valve penetration at bottom of drain pipe subject to plugging. Adjust flow at DV-9 to 60 gpm. Turbidity is now 72. Today's operation, repeat 60 gpm with 20% compression. At 1050 initiate backwash 1:37 remaining. May have short circuiting; lower view window can see pink balls, others are covered by sludge. Screw returns to 24 3/8. Operating parameters are 20% compression, 60 gpm. At 1105 hrs start run. Adjust turbidimeter flow so that flow to turbidimeter just tops the influent overflow weir inside the unit. Autosampler: resume program at 11:10, next sample (1st sample) in 28 minutes (1138 hrs). At 1520 hrs adjusted flow to turbidimeter, had no flow.
11/9/2001	Unit secured at 1345 hrs. At 1345 hrs backwash initiated. Unit will be secured until Monday morning.	Cleaned turbidimeter; no flow reestablished flow. At 1345 hrs secured FP1 and manually initiated backwash. Unit will be secured until Monday morning. Backwash will initiate once per day using C2 water.
11/10/2001	Unit secured until Monday (11/12/01).	No comments.
11/11/2001	Unit secured until Monday (11/12/01).	No comments.
11/12/2001	At 1025 hrs checked with graduated cylinder the effluent turbidity flow.	At 1000 hrs wrking startup of unit at following conditions of flow of 80 gpm and compression at 20%. Discovered "position transmitter failure" alarm on operator screen. Initiated manual backwash and will monitor if plate returns to preset 20% compression. Also reset alarm on alarm screen. Replumbed fuzzy filter effluent sampler and turbidity meter feed. After backwash, plate returned to 20% compression position (measured screw at 24 3/8"). Started unit up at 1025 hrs under 80 gpm feed condition. Feed pump #1 put into REMOTE position. Effluent sampler started at approximately 1045 hrs. Changed FF effluent sampler to pull sample every 30 minutes (vs 60 minutes). At 1215 hrs adjust HV10 valve full open and only getting 77 gpm to fuzzy filter, will run at this rate. Also noted bed pressure increasing from 4 to 4.3 psi (setpoint at 4.5 psi). At 1245 hrs cycled FP1 ON/OFF to confirm that WS1 overflow could handle feed water if FP1 shutdown (for example during fuzzy filter backwash). At curred feed flowrate, WS #1 will not overflow to floor. OK to run unattended.
11/13/2001	At 1049 hrs backwash cycle initiated by Bob Bucher. At 1245 hrs unit started.	At 0845 hrs flow loss to WS 1 tank - FP1 secured. At 0900 hrs flow returned to unit. From 0915 to 1000 hrs cleaned FF effluent turbidimeter. At 1049 hrs initiated 2nd backwash cycle. First backwash had FP1 still operational in REMOTE - due to not selecting C2 water for backwash source. Reset on facility PC to C2 water. At 1120 hrs 24:30 until next wash filter appears very dirty, as if wash had not occurred. Pressure is at 3.50 psi and compression is at 20%. Replumbing of autosample bucket looks good. gravity from FF to sample bucket, gravity overflow into drain form bucket, gravity overflow from bucket side port to turbidimeter. Today's test run: 30% compression at 40 gpm. At 1145 hrs flow problems - outside unit off, stole flow. Opened PV-4, closed PV-3, flood. Close PV-4. FP-1 won't run in AUTO, run in manual. Clean turbidity effluent line. Adjust flow to 40 gpm at DV-10 (from 98 gpm) to 45 gpm, rest using DV-9 recycle valve. Set bed compression to 26% and screw height of 20 7/8". At 1220 hrs initiated wash cycle, wash water flow of 39.6. Unit operational at 1245 hrs. Effluent sample started. At 1645 hrs switch sample collection taps - insufficiently flow from PVC/DV valve line, using bottom ball valve.
11/14/2001	Flow at 1305 600 mL/min.	At 1250 hrs 5 minutes into new filter cycle, CK turbidimeter flow - lots of solids settinling in turbidimeter. This unit is not ideal for primary influent. Drain and risne turbidimeter. Increase filter flow to 60 gpm. At 1305 hrs flow at 60.7 gpm, 30% compression. At 1320 hrs set new backwash pressure to 5.0 psi. Lots of solids in autosampler overflow bucket. Drain 1 rinse bucket. Rinse and backflush bucket feed line from FF effluent. Screw height at 20 7/8", touch screen shows 26% compression, touch screen reading 30" height, 26% compression. Flow from autosampler bucket drain at 450 mL / 12" (2.25 L/min) minimal flow from turbidity drain at this time. Backflush from turbidity to autosampler bucket - cleared air bubble, flow restored to 330 mL/30 minutes, or 0.66 L/min. High flows to plant testday and today due to rain, influent sewage should be dilute, expect much grit, fines, organic solids to wash in initially then dilute sewage. At 1343 hrs flow to FF at 58.5 gpm, open DV-10 a tad, flow increased to 62.6 gpm. Bob checking why FF elevator position and backpressure tags are integers in database. FF PLC is sending the
11/15/2001	Bed compression set at 30%, but reads as 26% on touch screen.	Flow to FF appears to be channeling up through back-wash drain side of FF. Lower view window on same side shows pink balls toward center; sludge blanket toward wall. Upper view window shows current above top plate circulating up wash-drain side and down filtrate drain side. Turbidity reading of 3.0. Good turbidity flow of 0.6 L/min. Effluent flow at 2 L/min from autosampler buckets plus 0.6 L/min. Solids accumulating in effluent autosampler bucket, also in turbidimeter. Drain and rinse bucket and turbidimeter cell, influent and effluent lines. Remove turbid serpentine flow path at influent side to increase flow and decrease settling, re-establish flow to bucket and turbidimeter. At 1218 hrs 30 minutes until next wash, intiate wash cycle. Fine sands and seeds visible between top plate and walls as plate rising. Washwater flow 37.5 gpm, up to 42 (1/2 turn in onCla-valve). New operation setting of 80 gpm, and 30% compression. Start time at 1235 hrs. DV-10 100% open, 73 gpm flow to FF. No flow to bucket, backflush ball valve to re-establish. Bucket flows 1.5 L/min to drain, 1.05 L/min to turbidimeter. Another rainy day, high plant flows, dilute wastewater.
11/16/2001	Bed compression set at 30%, but reads as 26% on touch screen. At 1425 hrs secured unit for weekend. Initiated backwash.	Autosampler not functioning, bob's fault - pulled grab sample at 0845 hrs. Plan to repeat run on Sunday-Monday. At 1015 hrs cleaned turbidimeter and returned to service, reading 42.38 NTU.
11/17/2001		No comments.
11/18/2001		No comments.
11/19/2001	Bed compression set at 30%, but reads as 26% on touch screen.	Today's run at 80 gpm and 30% compression. At 1140 hrs drain and clean autosampler bucket and turbidimeter. At 1155 hrs initiated wash, C2 flow of 62.5 gpm. FF spheres appear black below surface layer - not solid black. Maybe due to trapped fines. There were a lot of fines evident in window during sequences, Doe not squeeze out when top plate applied at 30% compression. Top screw measures at 20 15/16". At 1206 start filter run. Adjust flow at DV-10 valve to 80.2 gpm. At 1217 hrs turbidimeter flow of 1.87 mL/min. At 1230 hrs more than 1.2 the bed has accumulated solids, turbidity of 7.08. At 1235 hrs autosampler on, take sample turbidity of 6.9. At 1240 hrs appears that media breakthrough achieved, view through top window above top plate: solids swirling in eddy currents. flow appears to be channeling up along lower window (front wall), turbidity of 6.6, pressure of 3.68 and flow of 78.5 gpm. At 1254 turbidity of 6.5, good flow through turbidimeter. At 1415 hrs turbidity is 6.06, good flow through turbidimeter. At 1815 hrs reestablished flow to turbidimeter, turbidity of 48.73 NTU.

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11/20/2001	Bed compression set at 30%, but reads as 26% on touch screen. At 1250 hrs initiated a wash manually. At 1450 hrs secured unit and performed backwash. Unit secured for the holiday weekend.	At 0950 hrs cleaned turbidimeter. Pulled effluent sample from analysis 3 hours prior to end of run. Needs to be in lab. Turbidimeter flow ok. At 1230 hrs 10 minutes into new filter run. Empty autosample bucket, rinse, rinse and rain turbidimeter. Reestablish turbidity flow. At 1241 hrs turbidity of 31, pressure of 3.40, and flow of 72 gpm. Open DV-10 to 100% open, flow now 75.5 gpm, turbidimeter flow at 850 mL/min. At 1245 bed completely full of sludge, IE no pink balls visible. At 1250 hrs close ball valve on bottom of FF effluent pipe that leads to turbidimeter and autosampler. Initiate backwash clean turbidimeter and effluent autosampler bucket. At 1303 hrs start of new run. At 1309 hrs bucket and turbidimeter refilled and flow to turbidimeter drain. Turbidity is 18.8 NTU, turbidity flow at 880 mL/min. Sludge just accumulating around perimeter of bottom ball. At 1319 hrs start autosampler, turbidity of 29.4, sludge blanket beyond top of lower window. Some pink visible against glass on lower portion of lower window. Top screw returned to 20 3/4", reads 26% compression on touch screen. At 1457 hrs secured fuzzy filter unit
11/21/2001	Secured.	No comments.
11/22/2001	Secured.	No comments.
11/23/2001	Secured.	No comments.
11/24/2001	Secured.	No comments.
11/25/2001	Secured.	No comments.
11/26/2001	Secured.	No comments.
11/27/2001	Secured.	No comments.
11/28/2001	Secured.	No comments.
11/29/2001	Secured.	No comments.
11/30/2001	Secured.	No comments.
12/1/2001	Secured.	No comments.
12/2/2001	Secured.	No comments.
12/3/2001		No comments.
12/4/2001		
12/5/2001		
12/6/2001	Secured.	
12/7/2001	Secured.	
12/8/2001	Secured.	
12/9/2001	Secured.	
12/10/2001	Secured.	
12/11/2001	Secured.	
12/12/2001	Secured.	
12/13/2001	Secured.	
12/14/2001	Secured.	
12/15/2001	Secured.	
12/16/2001	Secured.	
12/17/2001	Secured.	
12/18/2001	Secured.	
12/19/2001	At 11:15 hrs, initiated C3 water flow with new C3 system configuration (PRV & CV). Control valve manually OPEN 100%	
12/20/2001	At 9:15 hrs, SCADA alarms - FF pressure switch high. At 8:36 hrs, FF2 turbidity alarm, At 12:30 hrs, secured unit for the weekend.	
12/21/2001		
12/22/2001		
12/23/2001		
12/24/2001		
12/25/2001		
12/26/2001		
12/27/2001		
12/28/2001		
12/29/2001		
12/30/2001	Adjustment for flow control: Scada 4-20 mA--> flow meter output 4-20 mA, SCADA 0-200 gpm--> flow meter 0-90 gpm.	
12/31/2001	At 15:45 hrs, backwash initiated to troubleshoot alarm on screen.	
1/1/2002		
1/2/2002	AT 12:25 hrs, C-3 pH, temp = 6.54/11.5	
1/3/2002	AT 12:46 hrs, start off new run, C-3 pH = 6.38, temp = 13.9, FF eff, pH = 6.35, temp = 13.5	
1/4/2002		
1/5/2002	At 12:50 hrs, adjusted feed flow 40--> 120 gpm	
1/6/2002		
1/7/2002	Eff pH - 6.72	
1/8/2002	1) At 11:55 hrs, Sludge/solids up the first 8" of side glass 315 mgd plant flow have been bypassing 2 throughout yesterday and this am (440 mgd peak last night). 2) At 14:10 hrs, inf grab 5 NTU, Eff grab 3 NTU	
1/9/2002	1) Hach ?? pH meter 7/4 buffer = 7.06/4.02 2) Jenco meter	
1/10/2002		
1/11/2002		
1/12/2002		
1/13/2002		
1/14/2002		
1/15/2002		
1/16/2002		20% comp, 160 gpm. 08:00 unit has gone through 2 sash cycles on pressure since noon yesterday. Start

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2/8/2002		11:00 appears there may be short circuiting, lower window is covered by sludge blanket, P = 3.7 psi, same as initial, 13:29' until next backwash, turbid effluent, 4.57 ntu online. Grab samples: in = 5.6, out = 6.2 ntu. Drain sample out of bottom of FF to see if floc is forming. Flush solids out of drain line. Fill 5 gal bucket. Get settling jar, stir bucket contents, decant into jar, observe: min, pin floc at most; 11 min- pin floc at most, no blanket. 11:30 raise top plate, top of media is clean. Bottom of media raised up- it was fully coated on underside. Decreased flow so media would fall off the bottom. Sludge penetration 2 to 4 inches into bed, interstitial space between balls only. Above this the balls all clean. 11:35 initiate wash. ~12:00at end of wash intercept plate on its way down, adjust plate lower stop to 20-5/8" (20% comp) 80 gpm (FCV @ 60%). 12:05 double alum dose to 98% speed (~28 mL/min alum). Turbidity = 3.0 online. DV-10 approx 1/3 closed. 12:43 online turb = 0.398, grab in = 4.3, grab out = 0.9. Jar test- sample from bottom of FF Observations: appears slightly turbid, some large particles that settle. Mostly fine suspended
2/9/2002		
2/10/2002		13:00 1) cleaned turbidimeter 13:20 2) initiated wash to prep for overnight run 3) set run for 120 gpm and alum dose of 50 mg/ (35.5 mL/min, 0.5548 gph), gph = (%speed) * (% stroke) * (2 gph). 14:10 4) set alum dosing @ 35 mL/min (69% speed, 40% stroke). 14:15 5) initiate run at following conditions; 120 gpm feed, 20% compression, 50 mg/L alum (35.5 mL/min), bed pressure wash set point = 5.5 psi.
2/11/2002	Eff turb dropping, 14:42 = 1.75 NTU, 14:49 = 0.970 NTU	14:30 = START time 80 gpm, 20% comp, 75 mg/L alum. 14:05 Decrease flow to 80 gpm from 120. Leave alum flow at 35.5 mL/min. Initiate wash. 14:10 alum flow = 35.5 mL/55", decrease stroke to ~36%, flow = 34 to 35 mL/min, 35.5 mL/59.8", 35.5 mL/61.6". 14:24 empty sample bottles, reset samplers, 1 st sample 15' from 15:26. Clean turbidimeter. 14:30 effluent grab (from bucket before new run) 3.6 ntu, infl. Grab 7.5 ntu.
2/12/2002	At 14:15, 40 gpm flow, alum @ 51% speed, flow just decreased from 80 gpm alum dropped from 69 to 51% speed. Turb 2.125 and dropping @ 1.932 @ 14:41.	(WVP started to receive 50 gpm high pH (10+) Tunneling .. Decant from Denny way CSO proj.) AT 13:10 hrs, start of new cycle, turb 7.6 NTU. Check alum flow :35 mL/60" (34 mL in 58.41"). AT 14:10 checklist FF eff turb = 2.25 NTU. Decreased flow to FF to 40 gpm, Decrease alum dose from 69% speed to 51. At 14:41 hrs, eff turbidity = 1.932. Empty sample containers. Increase alum speed to 60.
2/13/2002		At 17:00 hrs, secured alum addition to unit. Initial was and will run with no chemical overnight. At 18:33 hrs, initiated wash and emptied S8 sample bottle
2/14/2002		Bleach cleaning ref to 9/20/01 comments. *** Extended run repeat 120 gpm 20% comp no alum**** AT 11 :05 hrs, initiate backwash. (7:50 before next timed wash). For 200 ppm chlorine, 5.25% NaOCl. Vol ~ 180 gal = 680 L. 2.6 L to get 200 ppm (mg/L) NaOCl. The molecular wt of NaOCl is 74, 35/74 = 45% Cl. Have 12.5% bleach, add 2.6 L bleach. Dirty feed water. Turn DV-10 to close, 8 gpm leaking though. At 11:45 hrs, initiate wash. Add bleach solution through vent on top- drain side. Upstream of closed valve. First placed in manual @LCP after ven sprayed water all over when blower kicked on. At 11:55 hrs, place in auto, plate came down, once it was down, initiated wash (ven t was rinsed and hooked up again). Turn feed and rinse flow down to 10 gpm ea. @ facility computer. At 12:13 hrs, ean dof wash sstep, open DV-10 flow = 10 gpm. Allow to rinse through. At 12:27 hrs, initiate wash (8 min inot new filter run) 12:30 hrs, Leave flow for purge @ 10 gpm. At 12:50 hrs, SE turbidity ~ 9 NTU, was @ 13 this am @ start of shift. Per Rick Hammond- SE turbidimeter is accurate, even with the new bulb. (Note Denny Wy tunnel projf drilling decant 50 gpm started Tues) AT 13:20 hrs, Increase flow to 120 gpm, (40 for wash), 20% comp.
2/15/2002	At 9:30 hrs, shutdown unit to install 4" floex on feed line. At 10:40 hrs, unit back online, reduced flow to 80 gpm, AT 14:50 hrs, switched feed flow from 80-> 120, at 14:55 hrs, initiated wash	1) Unit secured for installation of 4 inch hose sections. Total of 120 ft of 4" hose added. At flow rates of : 40,60,80 and 120 gpm, the contact times are: 117, 78, 59 and 30 sec respectively. 2) Unit set to run over weekend under following conditions: no chem feed, 120 gpm, 20% compression, 5.5 psi bed pressure "backwash trigger"
2/16/2002		No comments.
2/17/2002		No comments.
2/18/2002		1) Setup for 24 hrs run with alum addition. Conditions: 80 gpm feed, 20% compression, 30 mg/L alum dose, 5.5 psi head pressure "backwash trigger". 30 mg/L = 14 mL/min on alum dosing pump (80 gpm). At 9:00 hrs, completed checklist, grab samples for turb. eff pH = 6.8, temp = 13.4 C, 4.9 NTU, inf pH = 4.8, 13.1 C 6.2 NTU. At 9:20 hrs, initiate wash. Appears to have been good solids penetration through media. View window - showed light soiling of media. As balls dropped off as plate rose- interior balls were dirty. Top of media below plate was clean. At 9:30 hrs, start autosamplers, 30' delay until 1st sample. 2) Alum dose 14.2 mL/min, 20% stroke, 50% speed. At 9:51 hrs, start pump 6 min after start of filter run. At 9:45 hrs, start of filter run. Alum flow = 14 mL/ 55.6", decrease speed to 48%. At 9:58 hrs, delay 1st S8 autosample until 10:30 14 mL/58.9". At 10:01 hrs, decrease flow to 80 gpm @ facility SCADA. At 10:10 hrs, initial P = 3.10 psi, set trip pressure at 5.0 psi. At 11:15 hrs, do cheek list, grab sample for floc observation from bottom of the filter. First clear out hose port. 0' No floc evident, 3': no floc evid
2/19/2002		**40 gpm, 30 mg/L alum, 20% comp** At 9:17 hrs, do check-list. At 9:20 hrs, small amount of sm (<0.5mm) floc in sample bucket (FF eff). Turb = 2.45 (rained last night, plant flow = ?, SE turb = ?. Increase sium flow from 48 to 57% speed. At 10:52 hrs, turb = 2.684 NTU. At 10:55 hrs, initiate wash, turn off alum. Switch feed flow to 40 gpm feed to allow more reaction time in hose. At 11:51 hrs, start alum @ 24% speed. At 11:55 hrs, start autosampler- first sample in 15 min run start @ 23:21 , 39' ago start ~ 11:15.
2/20/2002	At 17:30 hrs, initiated backwash , alum 40 gpm, 30 mg/L	1) At 11:15 hrs, complete checklist. AT 11:25 hrs, take sample from FF bottom do jar test. 1 min- no floc, 2 min-no floc, 5 min-no floc, 10 min-no floc. Floc visible in autsampler bucket ~0.5 mm & smaller. At 11:37 hrs, FF eff turb = 2.5 NTU (grab), FF inf turb = 7.3 NTU (grab) 2) At 18:15 hrs, unit completed wash and PACL coag introduced under following conditions: feed flow = 80 gpm, compression = 20%, coag dose = 30 mg/L PACL. Started samplers and will let run overnight. 3) At 18:20 hrs, cleaned effluent turbidimeter.
2/21/2002		1) Continued operating @ following conditions: feed flow = 80 gpm, compression = 20%, coag dose = 30 mg/L PACL. Will maintain through Friday sample collection.
2/22/2002	AT 16:20 hrs, reduced feed 80-40 pgm, reduced dosing pump 40 to 20% stroke	1) At 14:30 hrs, conference call with HDR (Jamie & JB). Based on data distributed from Wed-> Fri. Plan to run through weekend @ following conditions: Feed flow = 40 gpm, coag dose = 30 mg/L, compression = 20%. 2) Plan to download data on Monday morning and distribute for 13:00 hrs conf call. 3) At 16:20 hrs, changed operating condition per Note 1. PACL dose = 3.5 mL/min (30 mg/L \$ 40 gpm). 4) At 17:05 hrs, confirmed PACL dosing @ 3.5 mL/min. Dosing calculations for coagulant addition in log book pg 79.
2/23/2002		No comments.
2/24/2002		1) Around 15:15 hrs, cleaned eff turbidimeter. 2) Added PACL to current drum in use. Used masterflex pump to transfer to 5 gal buckets from full drum (no assess to remove/replace existing). Use care "top of run drum has residual PACL on it"!!!!
2/25/2002		1) S8 sampler did not run overnight!! Bob missed starting. Grabbed sample@ 10:30 hrs. 2) Check PACL coag dosing = 4 mL/min (~ 35 mg/L). 3) At 14:30 hrs, conference call with HDR led to following process change- based on data from weekend. Bed pressure set point changed from 5-> 4 psi. 4) At 14:30 hrs, cleaned effluent turbidimeter.
2/26/2002	Initially no flow- bled air from feed to trubidimeter.	**10% compression, 40 gpm, PACL 4 ml/min** Change compression to 10% (23-5/8 on screw). Refer to method on pg 68 (2/7/02). At 15:20hrs, initiate wash. At 15:22 hrs, empty sample bottles, reset samplers, 35 min delay until 1st sample. Clean turbidimer. Floc vident in eff sampoole bucket. Lots of 0.5 mm dia also 1-2 mm dia. PACL flow check 8.0 mL/207".
2/27/2002		No comments.
2/28/2002		No comments.

Date	Comments Entered on Operator Data Sheets	Comments from Operations Log Book
3/1/2002		**20% comp, 60 gpm** At 15:10 hrs, increase comp to 20%, initiate wash. 2) At 15:10 hrs, changed feed flow on SCADA 40 -> 60 gpm. Also adjusted PACL dose from 20 to 25% speed. Will check dose (mL/min). 3) At 16:20 hrs, checked PACL dosing = 5 mL/min. (30 mg/L set pt = 5.2 @ 60 gpm mL/min).
3/2/2002		No comments.
3/3/2002		No comments.
3/4/2002		** PACL 35 mg/L, 80 gpm, 20% comp*** 1) Looked @ weekend data, very few excursions above 2 NTU, those were short duration. Increase flow to 80 gpm. At 14:45 hrs, 45 min into new filter run. Increase flow from 60 to 80 gpm. Increase PACL from 25 to 33% speed (does = 6.0 mL/59.8 sec, 6 mL/min).
3/5/2002		1) 17:45 - 18:00 hrs, working on compression reset (20 -> 10%). Problems with PLC (OIS window - PLC not responding. Ended up cycling power and finally getting adjust ment correct. Planned run = 60 gpm @ 10% compression after discussion with HDR (Jamie) 2) AT 18:00 hrs, initiated wash cycle and cleaned turbidimeter. 3) At 18:05 hrs, restarted S8 sampler.
3/6/2002	pH S2 7.20/11.4	1) Missed flow change- ran overnight @ 80 gpm and 10% compression. 2) At 11:30 hrs, changed feed flow to 60 gpm @ lower coag dose (33-> 25% speed) 3) At 11:35 hrs, initiated wash to start new run.
3/7/2002		1) contined operation @ 60 gpm/10% compression. 2) S8 and S 14 samplers not started. Will rely on PLC data until re-starting samplers on Sunday morning.
3/8/2002		**10% compr, 100 gpm, dame PACL dose = 30** AT 13:00 check list. Downloade recent data)past 2 days) SE turbid varies between 3.5 and 6 NTU. Eff turb ~ 1.5 NTU. 16:00 hrs, chage flow set from 60 to 100 gpm. Increase PACL from 25% speed to 42% speed (calc. in log book pg 83). 16:02 wash was completed 46 min ago.
3/9/2002		No comments.
3/10/2002		No comments.
3/11/2002		No comments.
3/12/2002	S2 pH = 7.21 temp = 11.3C. 0646HR 3/12, FF1 pressure switch high alarm	At 15:25 hrs, stop PACL pump. Initiate wash. Empty autosample. Collection containers. Reset autosampler with 30 min delay until 1st sample. Drain and clean turbidimeter.
3/13/2002	S2 pH - 7.20, temp = 11	**10% comp, 30 mg/L PACL, 120 gpm** Review data, turbidity remained on avg below 2 NTU, w/o coag. At 15:27 hrs, start PACL, increase output from 42 to 50% speed (20% increase). Increase flow to 120 gpm. Initiate wash. 15:11 hrs 'till next wash. Empty sample containers, reset samplers, 30' delay until 1st sample. FF eff sample missed the container, hose was on outside.
3/14/2002		1) At 8:10 hrs, secured feed flow in support of drain system. Reconfiguration (BAF1 removal work). 2) At 8:20 hrs, feed flow returned to unit. Wash initiated- due to bed pressure > 4 psi for short duration. 3) At 14:00 hrs, decreased PACL dose from 50 to 25% speed complete checklist. 4) At 14:05, start autosampler with 30' delay until 1st sample. 5) At 14:05 hrs, initiate wash.
3/15/2002		1) Changed compression from 10% to 20%. Plan to run over weekend @ 120 gpm, 20%, 0 mg/L PACL. 2) At 16:20 hrs, cleaned turbidimeter. 3) At 16:18 hrs, initiated wash after adjusting compression. Also turned off metering pump (PACL).
3/16/2002		No comments.
3/17/2002		No comments.
3/18/2002	S2 pH = 7.18, temp = 11.5	** 120 gpm, 15 mg/L PACL (29% speed), 10% comp, 14:40 hrs, complete checklist. 1) Change compression to 10% , 23-5/8 on screw. 2) Clean turbidimeter. 3) 15:00 hrs, initiate wash. 4) Start PACL pump @ 25% speed, 20% stroke, dose = 32 mL-> 22, delta = 10mL/2'12.22". 4.55 mL/min = 13mg/L PACL (see pg 79 for sp gr). At 15:40 hrs, increase % speed from 25 to 29% speed. At 15:50 hrs, Empty sample containers.
3/19/2002		No comments.
3/20/2002	S2 pH = 7.18, temp = 8.2C. AT 16:50- PLC no response cycled power	1) AT 13:40 hrs, changed PACL dose 15-> 70 mg/L after discussion with Jamie (HDR). Want to check for improved TP removal. * Also restart4ed S8 sampler.
3/21/2002		**10% comp, 50 mg/L PACL, 120 GPM** At 14:10 hrs, initiate wash, sw off PACL. Unit is cycling too frequently, Pi ~ 3.6. P trip = 40. Increase Ptrip to 5.0. Decrease PACL to 50 mg/L= 17.5 mL/min. Try at 20% stroke, 62% speed. At 14:20 hrs, during wash palced in manual to increase Ptrip (pg 79). Oops-cancelled wash. At 14:20 hrs, started new wash. Flow check PACL 13 mL/min. Increase % speed to 85 = 34 mL/1'57". Decrease speed to 83 = 16 mL/57". Increase speed to 84%. Empty sample bottles, reset sampler, 30' delay.
3/22/2002	Note to Bob check PACL clairbration on 3/23	**Test of turbidity for wash step 7 (rinse at compression, no agitation) & of initial filter run ** Stop watch timer for step 7. Started after plate started coming down, was within 1" of media. At 14:11 hrs, stop-watch-timer for filter run started after touch screen timer reset. Observed valves on stop start to close & open, climbed down ladder and started watch timer. Use lab turbidimeter. The turbidity vs time data is in log book pg 87. 1) Based on lab data for P removal and phone conversation. change to 80 gpm, 70 mg PACL, Ptrip = 5 psi. 50 mg/L @ 120 gpm = 20% stroke, 84% speed. 70 mg/L @ 80 gpm = 20% stroke ~ 80% speed. Desired PACL dose = 16.3 mL/min. At 15:22 hrs, chage flow to 80 gpm, set PACL to 80% speed. PACL flow : can not measure, calib. column is full and drain. Ball valve is not functioning. At 15:31 hrs, clean turbidimeter, drain bucket. At 15:35 hrs, initiate wash. At 15:37 hrs, start autosamplers with 30' delay. At 15:40 hrs, fill sample bucket (was 1/2 full w/S8) with tap water so there is no air gap in turb tube. 2) WP Process lab TP results: 3/20/02 sample (120 gpm, 10% comp, 5 psi trip, 70 mg/L PACL)
3/23/2002		1) Downloaded PLC data, reviewed and concluded that filter runs > 3 hrs @ 80 gpm. On Saturday run will be- per decision matrix: 80 gpm, 10% compression, 5 psi BP trip, 70 mg/L alum. 2) At 9:27 hrs, check PACL dosing rate prior to switch to alum. PACL dosing = 11 mL/min (target 16.3 mL/min). At 11 mL/min, PACL dose ~ 50 mg/L. 3) At 9:30 hrs, switched to alum dosing at 70 mg/L. 70 mg/L alum ~ 32.7 mL/min. (80 gpm feed flow)->confirmed at 32 mL/min. 4) At 9:38 hrs, initiated wash for new run. 5) At 9:40 hrs, started samplers with 30 min delay.
3/24/2002	S2 pH = 7.33, temp = 11.5C	1) At 7:10 hrs, checked alum dose = 35 mL/min. 2) At 7:15 hrs, Noted lots of "floc" accumulated in sampler overflow bucket. Eff turbidity = 4.645 NTU with 21:47 on wash countdown timer. 3) At 7:26 hrs, initiated in preparation for next run. -Planned run: 100 gpm, 10% compression, trip P= 5.5 psi, PACL @ 70 mg/L. Running PACL @ 70 mg/L due to lower dose run on Friday-Saturday. 4) Cleaned turbidimeter and sample overflow bucket. Started S8 and S14 sampler with 30 min delay. 5) At 7:55 hrs, checked PACL dose = 20 ml/min.

Date	Comments Entered on Operator Data Sheets	Comments from Operations Log Book
3/25/2002		<p>Last day shut down prep: 1) clean filter (pg 15) - chlorine procedure. Target = 200 ppm bleach. Vol = 4x6 ~ 24 cu.ft ~ 185 gal. NaOCl = 12.5 % = 125000 ppm.= 1.09 L. At 9:15 hrs, decrease FF flow and wash flow to 20 gpm. Add 1 L bleasch through top on wash-waste to drain side, allow to mix in, for 5-10 min expand bed. At 9:25 hrs, initiate wash, bed expanded, placed in maual . At 9:30 hrs, added 0.2 L bleach, place in auto. Initiate wash, close DV-10, wash flow ~ 5.5. gpm. At 9:40 hrs, Open DV-10. Increase wash flwo to 40 gpm, FF flow to 40. At 9:50 hrs, Decrease flows to 10 gpm. At 9:52 hrs, Add 1L bleasch, close DV-10, flow - 0.0. At 9:55 hrs, place in auto,initiate wash. At 10:04 hrs, open DV-10, 1st few seconds @ > 120 gpm (sstage -4 of wash) Pinch DV-10 get flow to 10 gpm. At 10:12 hrs, end of step 6- plate back down, place in manual to cancel, place in auto. AT 10:13 hrs, initiate wash 10 gpm wash flow rate. Around 10:35 hrs, end of step 6, place in auto, increase feed flow to 100 gpm. At 10:43 hrs, decrease flow to 10 gpm. At 10:45 hrs, close DV-10, adjust top plate lower stop to decrease screw height</p>



Fuzzy Filter Pilot Unit Photos

Introduction

The following photos of the Schreiber Fuzzy Filter pilot unit were taken during the pilot testing. Each photo includes a caption and text boxes to point out key pieces of equipment.

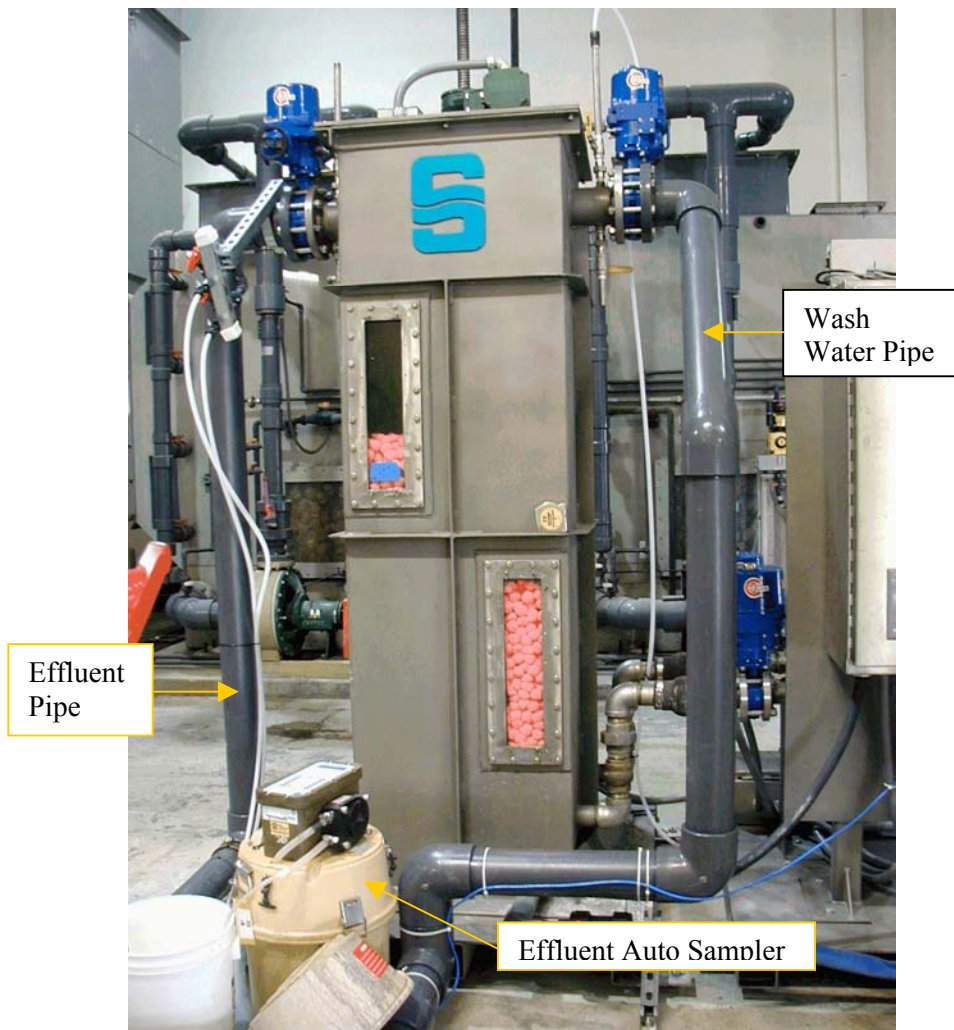


Figure 1. Schreiber Fuzzy Filter Pilot Unit

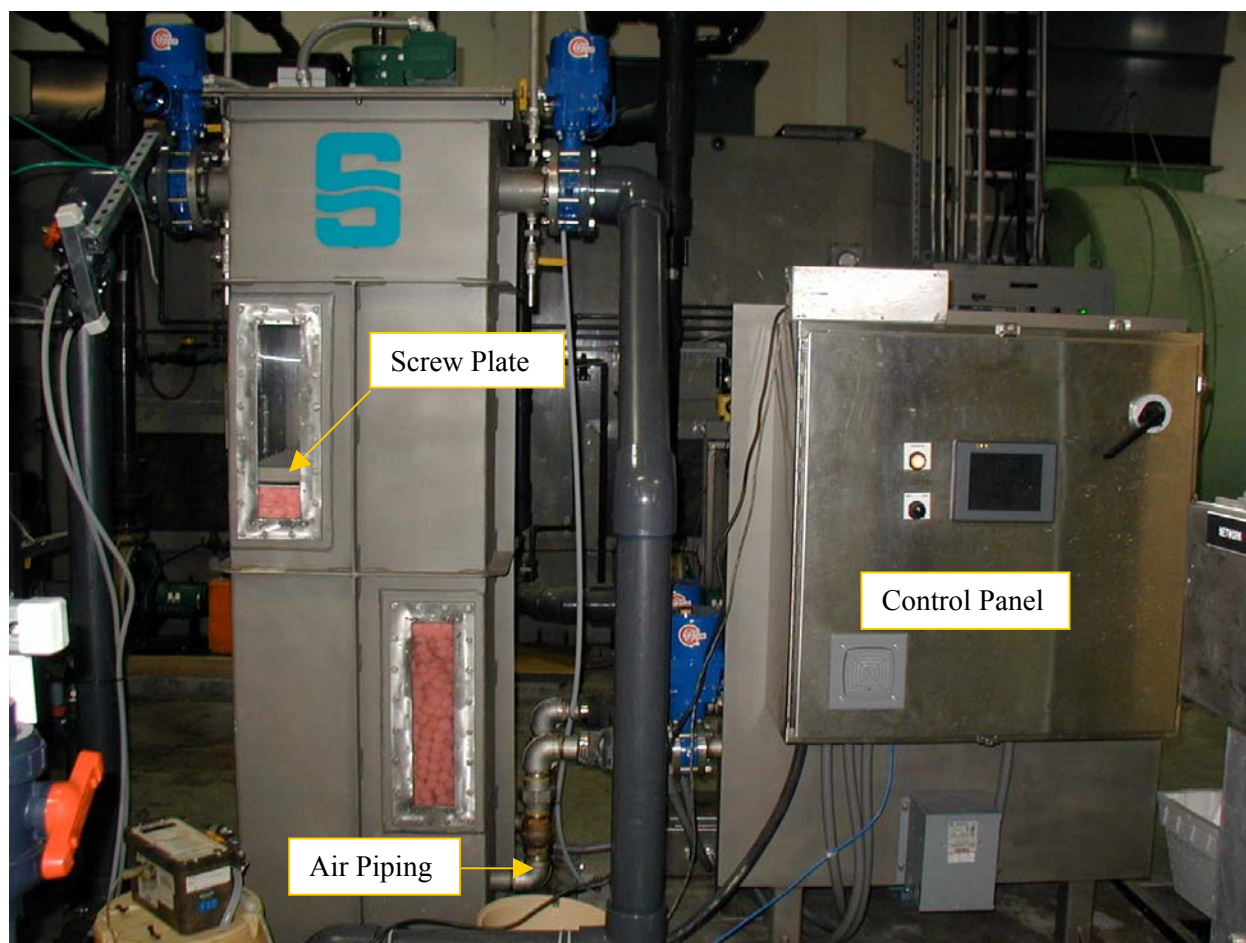


Figure 2. Schreiber Fuzzy Filter Pilot Unit & Control Panel

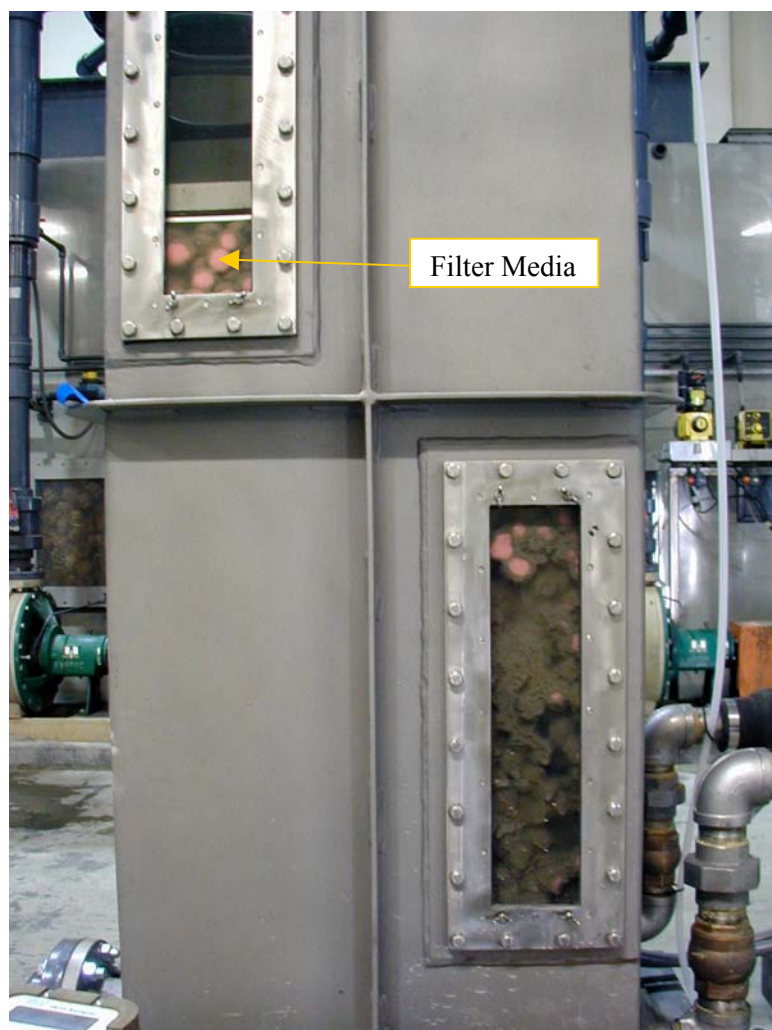


Figure 3. Fuzzy Filter with Primary Influent Feed